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INHERITANCE AND LINKAGE RELATIONS OF VIRESCENT SEEDLINGS IN MAIZE



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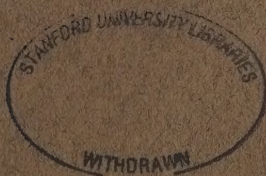
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OF VIRESCENT SEEDLINGS IN MAIZE

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INHERITANCE AND LINKAGE RELATIONS OF VIRESCENT SEEDLINGS IN MAIZE¹

I. F. PHIPPS²

In recent years an unusually large amount of data has been collected on the inheritance and genetic interrelations of chlorophyll deficiencies in different genera and species of plants. The species *Zea mays* has provided abundant suitable material for such a study, and consequently chlorophyll deficiencies in that species have been studied intensively.

Virescent seedlings, which show a type of chlorophyll deficiency, are white or yellow in the early seedling stage, later developing chlorophyll slowly but usually at such a rate as to permit the plants to survive after the endosperm reserves are used up.

Mature plants of virescent seedlings contain approximately the same amount of chlorophyll as do normal green plants.

The investigations reported in this paper include a study of the genetic interrelations between twelve different virescent seedlings, and of their linkage relations with other known factors in maize.

REVIEW OF LITERATURE

The first recorded case of virescent seedlings in maize with which the author is acquainted, is that recorded by Emerson (1912 b), who describes "white" seedlings, the older leaves of which become a "yellowish green and later a fairly strong green." This seedling type behaved as a simple Mendelian recessive to the normal green type. Miles (1915), who made a further study of these seedlings, showed, by intercrossing, that the "yellowish green" type was genetically different from the albino type.

Lindstrom (1918) studied the inheritance of a chlorophyll-deficient seedling to which he gave the name *Virescent* and which he symbolized as *v*. He examined the interrelations between virescent *v*, luteus *l*, and white *w*, seedlings. These interrelations, discussed further in two later papers by Lindstrom (1920, 1921), may be summarized as follows:

Green	Virescent white	Virescent yellow	Pure yellow	White
<i>L V W</i>	<i>L v W</i>	<i>l v W</i>	<i>l V w</i>	<i>L V w</i>
<i>l V W</i>			<i>l v w</i>	<i>L v w</i>

The virescent used by Lindstrom was reported by Stroman (1924 a) to be linked with the *A a* factor pair for anthocyanin pigment, a linkage which the writer has not been able to confirm.

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An extensive study of virescent seedlings was made by Demerec (1924). He demonstrated the existence of five genetically different types, and named them v_1 , v_2 , v_3 , v_4 , and v_5 . The mature-plant character fine-striped f (Lindstrom, 1918), which is virescent in the seedling stage, was shown to be genetically different and independent of virescents 1 to 5. Linkage tests indicated that v_1 belongs to the $C Sh Wx$ linkage group with approximately 7 per cent of crossing-over between $Wx wx$ and $V_1 v_1$, and that v_4 belongs to the $Ts_1 Lg B$ linkage group with approximately 7 per cent of crossing-over between $B b$ and $V_4 v_4$. The order of the genes in the above two groups is $C Sh Wx V_1$ and $Lg B V_4 Ts_1$. The linkage of $V_5 v_5$ with $Gl_1 gl_1$ and $Bn bn$ was demonstrated by Kvakan (1924). The order of the genes is either $Ra Bn Gl_1 V_5$ or $Ra Bn V_5 Gl_1$.

Carver (1927) reported two new virescents, v_6 and v_7 , both of which are linked with $Y y$, the order of the genes being $V_6 Y V_7$.

Demerec (1926 a) reported that a lethal virescent, v_8 , is linked with sugary endosperm, su , with a percentage of crossing-over of about 33.

MATERIAL AND METHODS

The material for this study was kindly provided by Professor R. A. Emerson, of Cornell University, and S. H. Emerson, of the University of Michigan. Many of the virescent stocks trace back to cultures of Hutchison (1922 a).

In the summer of 1924, S. H. Emerson made many intercrosses between a number of unknown virescents and virescents 1 to 5 and fine-striped. This material was given to the writer in April, 1925. Additional stocks segregating for virescent seedlings were supplied by Professor R. A. Emerson.

At the outset, both viable and lethal virescents were used; but all the lethal virescents were eliminated prior to the 1926 planting, leaving only those virescents which could be brought to maturity.

Mature plants from virescent seedlings frequently produce small and generally inferior ears. In such cases, intercrosses between virescents were obtained by using either F_1 -generation plants from a cross between a virescent and a linkage tester, or F_1 -generation plants from a cross between two virescents as female parents and homozygous virescents as male parents.

The methods used in making intercrosses between virescents of different origin may be classified as follows:

- I. Virescent $\times$ virescent
- IIa. F_1 of (virescent $\times$ linkage tester) $\times$ virescent
- b. Green segregates from the cross ($V v \times v v$) $\times$ virescent
- III. F_1 of (I) $\times$ virescent

The presence of virescent seedlings — all seedlings virescent or a ratio of 1 green to 1 virescent — in the progeny of such crosses indicates that the virescents concerned are allelomorphic to one another.

All crosses made in 1925 and 1926, together with the intercrosses made by S. H. Emerson, were carried to the F_2 generation, where a dihybrid ratio is conclusive proof that the parental virescents are genetically different. In 1927 an F_1 seedling progeny, consisting of green seedlings only and resulting from crosses made between virescents according to any one of the above methods, is considered as sufficient evidence to indicate that the parental virescents are genetically different.

Care was taken, especially in 1927, to insure that the parents were either homozygous or heterozygous virescents. All virescents were started in the greenhouse in two-inch pots and were transplanted as soon as they could be classified — usually just before the first leaf unfolded. For crosses to be made by methods II and III, a special planting was made of the F_1 generation of crosses which had given previously a 3:1 ratio (IIa) or a 9:7 ratio (III) in the F_2 generation. When backcross material was used (IIb), the seed was planted thickly in the field and thinned during the early seedling stage, leaving only the heterozygous green seedlings.

An attempt was made to repeat each cross at least twice. This was done with 102 out of the 138 possible crosses.

In 1927 two plantings, a normal and a very late planting, were made of F_1 -generation material designed to be used as female parents for intercrosses. Three plantings, an early, a normal, and a late planting, were made of all homozygous virescents. Three plantings of the latter were made also in 1925 and 1926.

The F_1 -generation seed of crosses between virescents and linkage testers was grown in the greenhouse during the winter. The virescent seedlings from the F_2 generations were transplanted from the greenhouse to the field in May, and the double recessive segregates were used in backcrosses. In this way two generations were obtained in one year.

The majority of the results reported were obtained from seedling counts made during the winter months. The seeds were planted in sand in benches in a greenhouse, the daily temperature of which was maintained at approximately 20° C. and the night temperature at approximately 16° C.

TERMINOLOGY

The following factors with their symbols are referred to in this paper:

A a = anthocyanin pigment. A factor pair for pigmentation of leaves, sheaths, husks, anthers, and aleurone. (Emerson, 1918, 1921 a.)

An an = anther ear. A semi-dwarf andromonoecious type. (Emerson and Emerson, 1922.)

- B b* = intensifier of plant color, supplementary to *A a* and *P pl*.
 (Emerson, 1921 a.)
Bh bh = blotched aleurone. Phenotypic expression in kernels of the
 constitution *A c R Bh* (Emerson, unpublished.)
Bn bn = brown aleurone. (Kvakan, 1924.)
C c = a factor pair for aleurone color complementary to *A a* and
R r. (East and Hayes, 1911; Emerson, 1918.)
Cr cr = crinkly leaf. (Emerson, 1921 b.)
D₁ d₁ = dwarf plant. (Emerson, 1912 c; Emerson and Emerson, 1922.)
D₃ d₃ = dwarf plant. (Demerec, 1926 a.)
F f = fine-striped leaves. (Lindstrom, 1918.)
Fl fl = floury endosperm. (Hayes and East, 1915.)
G g = golden plant. (Emerson, 1912 b; Lindstrom, 1918.)
Gm gm = germless seeds. (Demerec, 1923 b.)
Gl₁ gl₁ = glossy seedling. (Kvakan, 1924.)
I i = a factor pair which inhibits the production of aleurone color.
 (East and Hayes, 1911; Emerson, 1918.)
L₁ l₁ = luteus seedlings. (Lindstrom, 1917, 1918, 1921.)
Lg lg = liguleless leaf. (Emerson, 1912 a.)
P p = pericarp color. (Emerson, 1911; Anderson and Emerson,
 1923; Anderson, 1924 a.)
Pl pl = purple plant color. (Emerson, 1921 a.)
Pr pr = purple aleurone. (East and Hayes, 1911; Emerson, 1918.)
R r = a factor pair for aleurone color complementary to *A a* and
C c. (East and Hayes, 1911; Emerson, 1918, 1921 a.)
Ra ra = ramosa ear. (Gernert, 1912.)
Sh sh = shrunken endosperm. (Hutchison, 1921, 1922 b.)
Su su = sugary endosperm. (Correns, 1901; East and Hayes, 1911.)
Tu tu = tunicate ear. (Collins, 1917; Eyster, 1921.)
Ts₁ ts₁ = tassel seed 1, first published as *Te te*. (Emerson, 1920.)
Ts₂ ts₂ = tassel seed 2, first published as *Ts ts*. (Emerson, 1920.)
Ts₄ ts₄ = tassel seed 4. (Phipps, 1928.)
Wx wx = waxy endosperm. (Collins, 1909; Bregger, 1918.)
W₃ w₃ = white seedling (Lindstrom, 1918; Demerec, 1923 a.)
Y y = yellow endosperm. (Correns, 1901; East and Hayes, 1911;
 Anderson, 1924 b.)

Virescent seedlings:

- V₁ v₁* to *V₅ v₅* — (Demerec, 1924.)
V₆ v₆, *V₇ v₇* — (Carver, 1927.)
V₈ v₈ — (Demerec, 1926 a.)
V₉ v₉ to *V₂₀ v₂₀* — (Described in this paper.)

DESCRIPTION AND ORIGIN OF MATERIAL

The following descriptions of virescent seedlings are from observations made on seedlings grown in sand in a greenhouse maintained at a mean daily temperature of approximately 20° C. and a mean nightly temperature of approximately 16° C. Observations were made also on seedlings grown in the field during the summer months.

It was noted that the virescents recovered from the F₂ generation of certain crosses between a virescent and a linkage tester were phenotypically different from the virescent parent. Such behavior indicates that modifying factors affect the expression of the virescent character. The description of virescents 9 to 20, therefore, holds only for the virescents obtained from the original stocks.

An adequate description of virescents 1 to 5 is given by Demerec (1924), and of virescents 6 and 7 by Carver (1927).

Virescent 9, v₉

Young seedlings of virescent 9, when grown in the greenhouse during the winter, are almost completely devoid of chlorophyll. In the field, chlorophyll development is slow and frequently the seedlings die before sufficient chlorophyll has been produced to supply the needs of the plant. Mature plants are sometimes striped.

Virescent 9 came from Professor Hutchison's pedigree 608, which was the King Philip variety of red flint corn obtained from the Minnesota Experiment Station.

Virescent 10, v₁₀

Young seedlings of virescent 10 contain traces of chlorophyll and develop chlorophyll very rapidly; consequently they are most readily classified when in the very early seedling stage.

Virescent 10 came from Professor Hutchison's pedigree 619, which was the Silver King variety of white dent corn obtained from the Minnesota Experiment Station.

Virescent 11, v₁₁

Virescent 11 seedlings are similar to virescent 10 seedlings in that they develop chlorophyll very rapidly. Mature plants are a lighter green than the normal green plants of the same family.

Virescent 11 came from Professor Hutchison's pedigree 144, which was a white-capped yellow dent obtained from the Isbell Seed Company, Jackson, Michigan.

Virescent 12, v₁₂

Virescent 12 seedlings are indistinguishable from virescent 2 seedlings; they are almost perfectly white in the early seedling stage, but develop chlorophyll later. Virescent 12 can be grown to maturity without difficulty during the summer.

Virescent 12 came from Professor Hutchison's pedigree 158, which was the variety Pioneer, a white dent obtained from W. Oscar, Bismarek, North Dakota.

Virescent 13, v₁₃

The tip of the first leaf of virescent 13 is green at the time of emergence from the coleoptile. The remainder of the first leaf, and also the second leaf, are almost perfectly white and remain so for a considerable time even during the summer. This behavior makes classification relatively easy.

Virescent 13 came from Professor Hutchison's pedigree 504, which was a yellow flint obtained from the Central Experimental Farm, Ottawa, Canada.

Virescent 14, v₁₄

Virescent 14 is a yellowish green, semi-lethal virescent, which, like virescent 9, develops chlorophyll so slowly that many of the seedlings die soon after the endosperm reserves have become exhausted.

Virescent 14 came from Professor Hutchison's pedigree 490, which was the variety Triumph, obtained from the Montana Experiment Station.

Virescent 15, v₁₅

The upper half of the first leaf of virescent-15 seedlings is green; the lower half, and also the entire second leaf, are white. These seedlings are most readily classified during the late seedling stage.

Virescent-15 seedlings came from Professor Hutchison's pedigree 372, which was a Chinese yellow flint obtained from the Connecticut Experiment Station.

Virescent 16, v₁₆

Virescent 16, which is phenotypically the same as virescent 2 and virescent 10, came from Professor Hutchison's pedigree 194, a variety known as Seymour's Sweet Orange.

Virescent 17, v₁₇

Young seedlings of virescent 17 contain chlorophyll at the base of the leaves, and a trace at the tip. Greening of the leaves takes place from the base to the tip. In all the other virescents described, greening of the leaves begins at the tip and gradually extends toward the base.

Virescent 17 came from Professor Hutchison's pedigree 502, which was a white flint variety, Sanford, obtained from the Buck Seed Company of Boston.

Virescent 18, v₁₈

Virescent 18 is phenotypically the same as virescent 3, described by Demerec (1924).

Virescent 18 came from Dr. Brunson's pedigree 1136-5.

Virescent 19, v₁₉

Young seedlings of virescent 19 are almost perfectly white when grown in the greenhouse during the winter, but when grown in the field during the summer at high temperatures they develop chlorophyll very rapidly, making classification difficult and uncertain.

Virescent 19 came from Dr. Brunson's pedigree 1287-5.

Virescent 20, v₂₀

The midrib of virescent 20 becomes an intense green soon after emergence from the plumule sheath. The remainder of the leaf is white. Chlorophyll develops at approximately the same rate as in virescent 18.

Virescent 20 came from Professor Hutchison's pedigree 157.

INTERCROSSES BETWEEN DIFFERENT VIRESCENT STOCKS

In 1925, thirty-nine stocks of virescent seedlings were obtained from S. H. Emerson and Professor R. A. Emerson. Twelve of these stocks have been intercrossed and crossed with virescents 1 to 5 and fine-striped more completely than the remainder have been. A summary of these intercrosses is given in diagrammatic form in figure 1. Of a total of 138 possible crosses, 134 have been completed. All have given an entirely green seedling progeny in the F_1 generation, and, in cases in which the F_2 generation has been grown, they have given a dihybrid ratio of 9 green:7 virescent.

The untested combinations are $v_{12} \times v_3$, $v_{14} \times v_{12}$, $v_{17} \times v_{11}$, and $v_{18} \times v_{15}$.

As both virescent 12 and virescent 3 exhibit linkage with *Pr pr*, it is possible that they are allelomorphic, although, from the somewhat meager evidence available, the assumption that they are not allelomorphic is perhaps justifiable. Such evidence as is shown by the different percentages of crossing-over with *Pr pr*, by the fact that they are from widely different sources, and by the phenotypic differences between them, is discussed further under linkage tests with virescent 12. None of these three points of evidence is conclusive, because of the possibility of the existence of modifying factors affecting the percentage of crossing-over and the phenotypic expression of these characters, and of their possible independent origin by mutation.

The only evidence in support of the supposition that virescent 14 is genetically different from virescent 12, and that virescent 17 is genetically different from virescent 11, is that they are from unrelated stocks and that they are phenotypically different from each other.

Virescent 18 is shown to be linked either with *R r* or with a factor pair producing mottled aleurone, and is not linked with either *Sh sh* or *Wx wx*. Virescent 15 is shown to be linked with *C c Sh sh*, and *Wx wx*, and therefore it is almost certain that virescent 18 and virescent 15 are genetically different.

	9	10	11	12	13	14	15	16	17	18	19	20	
1	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₁	F ₂	F ₂	F ₂	F ₂	
2	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₁	F ₂	F ₁	F ₂	F ₂	
3	F ₁	F ₂	F ₂		F ₂	F ₂	F ₂	F ₁	F ₂	F ₁	F ₂	F ₂	
4	F ₁	F ₁	F ₂	F ₂	F ₂	F ₂	F ₂	F ₁	F ₂	F ₂	F ₂	F ₂	
5	F ₁	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₁	F ₁	F ₂	F ₂	F ₂	
6	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₂	F ₁	F ₁	F ₂	F ₂	F ₁	
7		F ₁	F ₁	F ₂	F ₁	F ₁	F ₁	F ₁	F ₁	F ₁	F ₂	F ₁	
8			F ₁	F ₁	F ₁	F ₁	F ₂	F ₁	F ₂	F ₁	F ₁	F ₁	
9				F ₁	F ₁	F ₁	F ₂	F ₁		F ₁	F ₂	F ₁	
10					F ₁		F ₂	F ₁	F ₁	F ₁	F ₂	F ₂	
11						F ₂	F ₁	F ₁	F ₂	F ₁	F ₂	F ₁	
12							F ₂	F ₁	F ₁	F ₁	F ₂	F ₁	
13								F ₂	F ₁	F ₁	F ₂	F ₁	
14									F ₁	F ₁	F ₁	F ₂	
15										F ₁	F ₂	LT	F ₁
16											F ₁	F ₁	F ₁
17												F ₁	F ₁
18													F ₁
19													
20													

LT=Linkage relations different

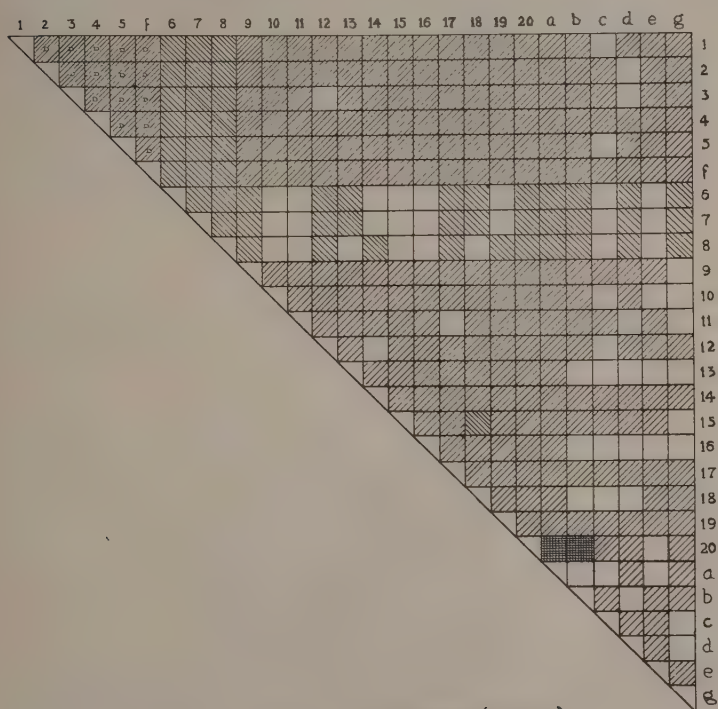
F₂ = F₂-generation results from intercrosses

F₁ = F₁-generation results from intercrosses



FIGURE 1. INTERCROSSES BETWEEN VIRESCENTS 9 TO 20, AND CROSSES WITH VIRESCENTS 1 TO 5 AND FINE-STRIPED

Intercrosses which have been made between all known virescents are presented in diagrammatic form in figure 2.



▨ Intercrosses made by Demerec (1924)

□ Not intercrossed (group I)

▩ Not intercrossed but probably not allelomorphic (group II)

▨ Not allelomorphic (group III)

▩ Allelomorphic (group IV)

FIGURE 2. INTERCROSSES THAT HAVE BEEN MADE BETWEEN ALL THE KNOWN VIRESCENTS

Two intercrosses, $v_a \times v_{20}$ and $v_b \times v_{20}$, gave virescent seedlings in the F_1 generation.³ Virescents of the three stocks v_a , v_b , and v_{20} , are therefore allelomorphie. These two intercrosses are crosshatched as in group IV (legend to figure 2). Intercrosses which indicate that the virescents concerned are not allelomorphie are shown by crosshatching as in group III. If a certain virescent is known to belong to a particular linkage group, then other virescents which do not show such a linkage are considered to be genetically different from that virescent. For example, virescent 8 has not been intercrossed with virescent 12, but virescent 8 is linked with *Su su* while virescent 12 is inherited independently of *Su su*; therefore virescent 8 and virescent 12 are probably genetically different. Such cases are shown by crosshatching as in group II.

LINKAGE TESTS

An attempt was made to cross each virescent with a complete set of linkage testers.⁴ The virescents were naturally tested more completely with endosperm, aleurone, and seedling characters, than with plant or cob characters.

Linkage tests with virescent 2

Virescent 2 has been tested by other workers with *W w* (Lindstrom, 1918), *L_1 l_1* (Lindstrom, 1918), *Pl pl* (Stroman, 1924 a), *Bb bn* (Kvakan, 1924), and *Tu tu* (Eyster, 1921), and has been shown to be inherited independently of each of these factor pairs. A cross between virescent 2 and the virescent used by Lindstrom (1918) gave all virescent seedlings in F_1 , indicating that these two virescents are allelomorphie. The virescent used by Stroman (1924 a) is stated to be the same as that used by Lindstrom (1918).

Tests of $V_2 v_2$ with $A a$

Stroman (1924 a) reported that $V_2 v_2$ is linked with $A a$ with 45 per cent of crossing-over. Second- and third-generation data are presented to support this hypothesis. The F_2 -generation data presented in table 11 (Stroman), when fitted to an hypothesis of 45 per cent crossing-over, give odds of 1 to 1 against such a deviation being due to chance alone. The data when calculated to fit an hypothesis of independent inheritance, give odds of 6 to 1 against such a deviation being due to chance alone. The χ^2 method for calculating goodness of fit is of no value in distinguishing between these two hypotheses, since the odds obtained with either hypothesis are well within the limits of variation imposed by random sampling. Consequently, from such data as are here presented, one cannot conclude that $A a$ and $V_2 v_2$ are linked.

³ Virescents v_2 to v_7 are virescents which are named provisionally, and are included here because of their relations with known virescents.

⁴ The author wishes to thank Professors Emerson, Fraser, and Wentz for their kindness in providing mature plants of various linkage testers during the summer of 1925.

The F_3 progenies presented in summary in tables 12, 13, 15, and 16 (Stroman) are classified, by means of the χ^2 method, into coupling and repulsion phases. Again such results do not furnish any evidence for linkage, since almost any large F_3 generation, segregating for two independent factors and including a large number of progenies but small numbers in each progeny, can be separated into two classes which suggest the coupling and the repulsion phases of linkage as based on an hypothesis of 45 per cent of crossing-over.

A large number of backcrosses have been made between $V_2 v_2$ and $A a$. The complete data are presented in tables 16 and 17 (appendix), and are summarized in table 1.

TABLE 1. SUMMARY OF THE PARENTAL AND NEW COMBINATION CLASSES OF TABLES 16 AND 17

Table	Parental combinations	New combinations	Total
16.....	205	201	.....
17.....	815	816	.....
Observed.....	1,020	1,017	2,037
Calculated 1:1.....	1,018.5	1,018.5	2,037
Difference.....	1.5 $\pm$ 15.2		.....

The progeny of the backcross ($A V_2 . a v_2$) $\times$ ($a v_2 . a v_2$) is recorded in table 16. The parental and new combination classes give a deviation from the calculated 1:1 ratio of 2.0 ± 6.80 . In table 17 is recorded the progeny of backcrosses in which the constitution of the F_1 parent was ($A v_2 . a V_2$). The parental and new combination classes give a deviation from the calculated 1:1 ratio of 0.5 ± 13.6 . The total parental and recombination classes of tables 16 and 17 give a deviation from the calculated 1:1 ratio of 1.5 ± 15.2 (table 1). The obvious conclusion from these data is that $V_2 v_2$ and $A a$ are inherited independently of each other.

Linkage test of $V_2 v_2$ with $Pr pr$

An indication of linkage of $V_2 v_2$ with $Pr pr$ was obtained in 1926. Backcrosses were made in 1927 in order to study further this indication of linkage. The seedling counts from thirteen such backcrosses are presented in table 18 (appendix). The deviation from equality of the parental and new combination classes is 144 ± 14.2 . The odds against such a deviation being due to chance alone are greater than 1,000,000,000 to 1. The data fit an hypothesis of 41.9 per cent of crossing-over. It has not been possible to determine the actual constitution of the F_1 parent in pedigrees 2747

and 2748, but the seedling progenies, when added together, indicate the repulsion phase of linkage. Even if a progeny which exhibited the coupling phase were added into the total, the deviation would be decreased and not accentuated.

The progeny of one family exhibiting the coupling phase of linkage is presented in table 19. The parental and new combination classes give a deviation from equality of 15.5 ± 4.83 . The odds are approximately 65 to 1 against such an occurrence being due to chance alone. The data fit an hypothesis of 42.4 per cent of crossing-over. The results presented are considered as fairly good evidence that $V_2 v_2$ and $Pr pr$ are linked, but further results, especially larger numbers in the coupling phase of linkage, are necessary before one can conclude with certainty that these two factor pairs belong to the same linkage group.

Linkage tests of $V v_2$ with $D_1 d_1$, $Su su$, $R r$, $Bh bh$, and $Y y$

A summary of linkage tests between $V v_2$ and the five factors listed above is given in table 2. The detailed data are presented in tables 20 to 24 (appendix).

The F_2 seedling progenies of two pedigrees segregating for $V_2 v_2$ and $Su su$ are presented in table 21. The germination of the sugary kernels was poor, and therefore the agreement between the observed and calculated values was determined on the basis of a segregation of 3 green to 1 virescent seedling independently in the starchy and sugary classes. A deviation of 1.75 ± 4.20 from a segregation of 3 $V_2 v_2$: 1 v in the starchy class, and a deviation of 2.5 ± 2.07 in the sugary class, are considered as sufficient evidence that $V_2 v_2$ and $Su su$ are inherited independently of each other.

The results presented in table 2, when calculated on the basis of independent inheritance, justify the conclusion that $V_2 v_2$ either is inherited independently of, or is not very closely linked with, $D_1 d_1$, $Su su$, $R r$, $Bh bh$, and $Y y$.

Linkage tests with virescent 3

It has been shown by Demerec (1924) that virescent 3 is inherited independently of $Wx wx$, $A a$, $R r$, $Su su$, and $Lg lg$.

Linkage of $V_3 v_3$ with $Pr pr$

Six F_1 plants of the constitution $\frac{pr V_3}{Pr v_3}$ were backcrossed to the double recessive $\frac{pr v_3}{pr v_3}$, and gave 225 crossovers out of a total of 841 individuals. These results fit an hypothesis of 26.8 per cent of crossings-over between $V_3 v_3$ and $Pr pr$. Detailed data are given in table 25. Unfortunately no crosses involving the coupling phase of linkage were obtained.

Virescent 3 when crossed with virescent 2, which is probably also linked with $Pr pr$, gave green seedlings in F_1 , and 125 green to 114 virescent

TABLE 2. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_2 v_2$ IS INHERITED INDEPENDENTLY OF $D_1 d_1$, $Su su$, $R r$, $Bh bh$, AND $Y y$

Genes involved		$V X^*$	$v x^*$	$V x$	$v X$	Total	χ^2 †	$D \pm \ddagger$	Table in which complete data are given
$D_1 d_1$	Observed.....	75	7	29	25	136	0.7843	.....	20
	Calculated 9:1:3:3....	76.5	8.5	25.5	25.5	136			
$Su su$	Observed.....	157	15	35	50	257		Su 1.75 ± 4.20	su 2.5 ± 2.07
	Calculated $Su 3:1, su 3:1$	155.25	12.5	37.5	51.75	257			
$R r$	Observed.....	89	29	72	27	217	1.9248	.....	22
	Calculated 3:1:3:1....	81.375	27.125	81.375	27.125	217			
$Bh bh$	Observed.....	130	12	35	38	215	1.6649	.....	23
	Calculated 9:1:3:3....	120.94	13.44	40.31	40.31	215			
$Y y$	Observed.....	115	137	134	128	514	....	5.0 $\pm$ 7.65	24
	Observed combinations..	252		262		514			
	Calculated 1:1.....	257		257		514			

* X, x = any one of the genes listed under "Genes involved."† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.‡ A $P. E.$ value of 3.2 gives odds of 31.36 to 1.

seedlings in F_2 , thus demonstrating that $V_2 v_2$ and $V_3 v_3$ are genetically different. In such a cross ($V_2 V_2 v_3 v_3 \times v_2 v_2 V_3 V_3$), complete linkage would give a 1:1 ratio in F_2 ; consequently a very large F_2 population is necessary in order to distinguish between a 9:7 ratio and a ratio intermediate between this and a 1:1 ratio. The F_2 results above, when calculated on the basis of a 9:7 and a 1:1 ratio, gave odds against such an occurrence being due to chance alone of 3.5 to 1 and 1.09 to 1, respectively. The odds in both cases are within the limits imposed by random sampling. Therefore, from such results, one cannot conclude that $V_3 v_3$ and $V_2 v_2$ are linked.

Test of $V_3 v_3$ with $D_1 d_1$, $Su su$, $Pl pl$, and $Y y$

A summary of data from linkage tests with virescent 3 is given in table 3. The results when calculated on the basis of independent inheritance indicate that $V_3 v_3$ is inherited independently of $D_1 d_1$, $Su su$, $Pl pl$, and $Y y$.

Linkage tests with virescent 8

Linkage of $V_8 v_8$ with $Tu tu$

Demerec (1926 a) has shown that $V_8 v_8$ and $Su su$ are linked with about 33 per cent of crossing-over. Jones and Gallastegui (1919) reported that $Su su$ and $Tu tu$ belong to the same linkage group. Eyster (1921) pre-

TABLE 3. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_3 v_3$ IS INHERITED INDEPENDENTLY OF $D_1 d_1$, $Su su$, $Pl pl$, AND $Y y$

Genes involved		$V X^*$	$v x^*$	$V x$	$v X$	Total	χ^2 †	$D \pm \dagger$	Table in which detailed data are given
$D_1 d_1$	Observed.....	117	194	112	112	435			
	Observed combinations.	211		224		435			
	Calculated 1:1.....	217.5		217.5		435	....	6.5 ± 7.03	26
$Su su$	Observed.....	85	60	75	81	301			
	Observed combinations.	145		156		301			
	Calculated 1:1.....	150.5		150.5		301	....	5.5 ± 5.85	27
$Pl pl$	Observed.....	28	23	24	24	99			
	Observed combinations.	51		48		99			
	Calculated 1:1.....	49.5		49.5		99	....	1.5 ± 3.36	28
$Y y$	Observed.....	65	24	25	64	178			
	Calculated 3:1:1:3.....	66.75	22.25	22.25	66.75	178	0.6367	.....	29

* X, x = any one of the genes listed under "Genes involved."† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.† A $\frac{D}{P.E.}$ value of 3.2 gives odds of 31.36 to 1.

sented more extensive data and reported that the percentage of crossing-over between these two factors is about 30.

In 1927 Professor Emerson furnished the writer with a number of F_2 ears segregating for $Su su$, $Tu tu$, and $V_8 v_8$. Virescent 8 is a lethal virescent which does not usually develop sufficient chlorophyll to maintain the life of the plant after the endosperm reserves are used up. A linkage with $Tu tu$, therefore, will be expressed by a deficiency of the tunicate or the non-tunicate class, depending on whether the F_1 plant exhibits the coupling or the repulsion phase of linkage.

The F_2 -generation progeny of the cross $\frac{Su V_8 Tu}{Su V_8 tu} \times \frac{su V_8 tu}{su v_8 tu}$ is recorded in table 30. Section A of this table records the segregation of $Su su$ and $Tu tu$ in families which are segregating for virescent 8. Out of a total of 226 plants, not a single non-tunicate plant was obtained. The F_1 plants carried the allelomorphs of $V_8 v_8$ and $Tu tu$ in the coupling phase, and therefore in the non-tunicate class only those plants which represent crossovers will survive the seedling stage. It is obvious, then, that $V_8 v_8$ and $Tu tu$ are very closely linked.

The segregation of $Su su$ and $Tu tu$ on those ears which do not segregate for virescent 8 is given in section B, table 30.

The F_2 progeny of the cross $\frac{Su V_8 tu}{Su v_8 tu} \times \frac{su V_8 Tu}{su V_8 tu}$ is recorded in table

31. Section A of this table records the segregation of *Su su* and *Tu tu* in families which segregate for $V_8 v_8$. One crossover — one non-tunicate plant — was obtained out of a total of 225 plants. The segregation of *Su su* and *Tu tu* on those ears which do not segregate for $V_8 v_8$ is given in section B, table 31.

The segregation of $V_8 v_8$ and *Tu tu* in tables 30 and 31 is summarized in table 4.

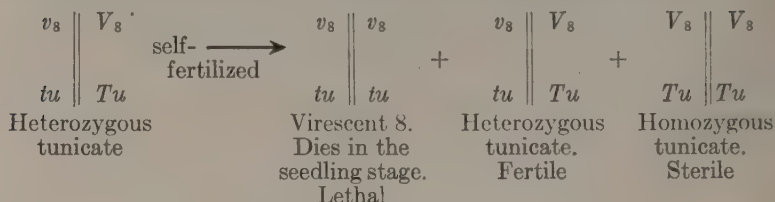
TABLE 4. SUMMARY OF F_2 PROGENIES OF THE CROSS $\frac{Tu V_8}{tu v_8}$

Table	V_8		v_8	
	<i>Tu</i>	<i>tu</i>	<i>Tu</i>	<i>tu</i>
30.....	226	0	.....	.....
31.....	224	1	.....	.....
Total.....	450	1	.....	.....

In the V_8 class (table 4), 450 tunicate plants and 1 non-tunicate plant were obtained, indicating that the percentage of crossing-over between $V_8 v_8$ and *Tu tu* is less than one. The order of the genes may therefore be either *Su Tu V_8* or *Su V_8 Tu*. If the order of the genes is *Su Tu V_8*, then the one crossover, which is *su tu V_8*, is a double crossover; but if the order is *Su V_8 Tu*, then the one crossover is a single crossover. One exceptional case was noted. Pedigree 3205 (17452-10) gave 24 green to 3 virescent seedlings in the greenhouse, but field counts from seed from the same ear gave 20 tunicate to 9 non-tunicate plants. The latter approximates a 3:1 ratio and is not in conformity with results obtained from other ears in the same pedigree; consequently pedigree 3205 is omitted until a further study will have been made of this apparently abnormal behavior.

The inheritance of tunicate maize plants was studied by Collins (1917), who concluded that the ordinary type of tunicate plants represents a case of imperfect dominance and that it is unfixable because homozygous tunicate plants are sterile. Jones and Gallastegui (1919) and Eyster (1921) also found that homozygous tunicate plants are sterile. This being the case, then, a plant of the constitution $\frac{V_8 Tu}{v_8 tu}$, when self-fertilized, will produce only one genotype with which the strain may be perpetuated. The progeny of this plant and in turn its progeny, will remain constant, except for an occasional crossover. This type of behavior may be said to be produced by a "balanced heterozygote." From the standpoint of the perpetuation of the type, it simulates the balanced lethal situation in *Drosophila* as reported by Muller (1918).

The balanced heterozygote behavior is diagrammed below:



Linkage tests with virescent 9

A summary of linkage tests with $V_9 v_9$ is given in table 5. The complete data are recorded in tables 32 to 36. The results indicate that $V_9 v_9$ is inherited independently of $Sh sh$, $C c$, $R r$, $Y y$, and $Su su$.

TABLE 5. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_9 v_9$ IS INHERITED INDEPENDENTLY OF $Sh sh$, $C c$, $R r$, $Y y$, AND $Su su$

Genes involved		$V_9 X^*$	$v_9 x^*$	$V_9 x$	$v_9 X$	Total	$\chi^2 \dagger$	$D \pm \ddagger$	Table in which detailed data are given
$Sh sh$	Observed.....	72	22	66	16	176	2.1819	.....	32
	Calculated 3:1:3:1.....	66	22	66	22	176			
$C c R r$	Observed.....	34	30	104	8	176	....	.....	33
	Calculated 3:3:9:1.....	33	33	99	11	176			
$R^r R^k$	Observed.....	28	26	28	31	113	....	2.5 ± 3.58	34
	Observed combinations.....	54		59		113			
	Calculated 1:1.....	56.5		56.5		113			
$Y y$	Observed.....	64	9	26	31	130	3.1418	.....	35
	Calculated 9:1:3:3.....	73.125	8.125	24.375	24.375	130			
$Su su$	Observed.....	144	8	42	48	242		Su 0	36
	Calculated $Su 3:1, su 3:1$	144	12.5	37.5	48	242		su 4.5 $\pm 4.05 \mid \pm 2.07$	

* X, x = any one of the genes listed under "Genes involved."

† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.

‡ A $\frac{D}{P.E.}$ value of 3.2 gives odds of 31.36 to 1.

Linkage tests with virescent 10

The linkage tests made with virescent 10 are given in tables 37 to 39, and summarized in table 6. The linkage test with luteus (table 39) gave 358 green, 77 virescent white, and 25 luteus seedlings. These results suggest a 12:3:1 ratio. The results indicate that virescent 10 is inherited independently of $An an$, $A a$, and an unknown luteus ($L l$)

TABLE 6. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_{10} v_{10}$ IS INHERITED INDEPENDENTLY OF $An\ an$, $A\ a$, AND $L\ l$

Genes involved		$V_{10}\ X^*$	$V_{10}\ x^*$	$v_{10}\ X$	$v_{10}\ x$	Total	χ^2 †	Table in which detailed data are given
$An\ an$	Observed	482	167	181	53	883		
	Calculated 9:3:3:1	496.69	165.56	165.56	55.19	883	1.9738	37
$A\ a$	Observed	90	39	20	9	158		
	Calculated 9:3:3:1	88.875	29.625	29.625	9.875	158	6.1856	38
$L\ l$	Observed		358	77	25	460		
	Calculated 12:3:1		345	86.25	28.75	460	1.9710	39

* X, x = any one of the genes listed under "Genes involved."

† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.

Linkage tests with virescent 12

Linkage of $V_{12} v_{12}$ with $Pr\ pr$

In table 40 is recorded the F_2 progeny of twelve ears of the cross $V_1\ Pr \times v_{12}\ pr$. The data recorded show a percentage of crossing-over of 11.4.

Three F_1 ears of the constitution $\frac{V_{12}\ Pr}{v_{12}\ pr}$ were backcrossed to the double recessive $\frac{v_{12}\ pr}{v_{12}\ pr}$, and gave 19 crossovers out of a total of 153 individuals (table 41). This indicates a percentage of crossing-over of 12.4.

It has been shown that $V_3\ v_3$, and possibly $V_2\ v_2$, are linked with $Pr\ pr$. Virescent 12 when crossed with $V_2\ v_2$ gave green seedlings in F_1 and a 9:7 ratio in F_2 , indicating that $V_2\ v_2$ and $V_{12}\ v_{12}$ are not allelomorphic. Unfortunately $V_3\ v_3$ and $V_{12}\ v_{12}$ have not been intercrossed successfully. There is, therefore, the possibility that $V_3\ v_3$ and $V_{12}\ v_{12}$ are allelomorphic, although the small amount of evidence available indicates that they are not allelomorphic. They are of an entirely different origin, $V_{12}\ v_{12}$ coming from a white-dent commercial strain of maize from Bismarek, North Dakota, and $V_3\ v_3$ coming from the progeny of a cross made by Professor Emerson between a sweet corn and a white rice pop corn. Further, the percentage of crossing-over between $V_{12}\ v_{12}$ and $Pr\ pr$ is about 12, and between $V_3\ v_3$ and $Pr\ pr$ about 27; consequently, $V_3\ v_3$ and $V_{12}\ v_{12}$ have been provisionally classified as two different virescents, since the little evidence available points in that direction.

Tests of $V_{12} v_{12}$ with $Sh\ sh$, $Su\ su$, $Y\ y$, $Fl\ fl$, $Lg\ lg$, and $A\ a$

Virescent-12 linkage tests with $Sh\ sh$, $Su\ su$, $Y\ y$, $Fl\ fl$, $Lg\ lg$, and $A\ a$, indicate that $V_{12}\ v_{12}$ is inherited independently of each of these characters.

The detailed data are presented in tables 42 to 47, and summarized in table 7.

TABLE 7. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_{12} v_1^2$ IS INHERITED INDEPENDENTLY OF $Sh sh$, $Su su$, $Y y$, $Fl fl$, $Lg lg$, AND $A a$

Genes involved		$V_{12} X^*$		$v_{12} x^*$		Total	$\chi^2 \dagger$	$D \pm \ddagger$	Table in which detailed data are given
		V_{12}	X^*	v_{12}	x^*				
$Sh sh$	Observed.....	479	23	81	170	753		$\frac{Sh}{7.75} \pm 1$	
	Calculated $9:1:3:3$	486.75	26	78	162.25	753		± 2.98	42
$Su su$	Observed.....	364	43	103	114	624			
	Calculated $9:1:3:3$	351	39	117	117	624	2.6439		43
$Y y$	Observed.....	37	5	14	13	69			
	Calculated $9:1:3:3$	38.81	4.31	12.94	12.94	69	0.2820		44
$Fl fl$	Observed.....	46	18	44	18	126			
	Calculated $3:1:3:1$	47.25	15.75	47.25	15.75	126	0.8994		45
$Lg lg$	Observed.....	227	25	75	76	403			
	Calculated $9:1:3:3$	226.69	25.19	75.56	75.56	403	0.0086		46
$A a$	Observed.....	65	59	68	63	255			
	Recombinations.....	124		131		255			
	Calculated $1:1$	127.5		127.5		255	....	3.5 ± 5.39	47

* X, x = any one of the genes listed under "Genes involved."

† A^2 value of 9.0000 for four classes gives odds of 34 to 1.

‡ A^D value of 3.2 gives odds of 31.35 to 1.

Linkage tests with virescent 13

Linkage of $V_{13} v_{13}$ with a gene producing mottled aleurone

An unknown mottled-aleurone plant was crossed with a virescent-13 plant of the constitution $A c r v_{13}$. The F_1 -generation kernels were all mottled. In the F_2 generation a ratio of 9 mottled to 7 colorless kernels was obtained. The segregation of $V_{13} v_{13}$ in the mottled and non-mottled classes (table 50) indicates a linkage between $V_{13} v_{13}$ and one of the two factors which are segregating for aleurone color. The percentage of crossing-over which gives the best fit is 12.0, but the fit is poor since the colored-virescent class is deficient. The constitution of the mottled parent as regards $C c$ and $R r$ is unknown. If the unknown aleurone pattern is stippled ($St st$), then $V_{13} v_{13}$ should exhibit linkage with $R r$, since $St st$ is either very closely linked with, or allelomorphic to, $R r$. The results recorded in tables 48 and 49 indicate that $R r$ and $V_{13} v_{13}$ are independent. The unknown aleurone pattern may possibly be blotched aleurone, which is very closely linked with $Pl pl$ (Emerson, unpublished data). $Pl pl$ and $Y_1 y_1$ belong to the same linkage group and are about 30 units apart. Therefore, assuming that the unknown aleurone pattern is Bh

bh, $V_{13} v_{13}$ should show a linkage with $Y y$ of either about 42 per cent or about 18 per cent of crossing-over. A linkage test between $V_{13} v_{13}$ and $Y y$ is recorded in table 54. The results fit an hypothesis of independence, but the total number of individuals is small and a percentage of crossing-over of 42 in an F_2 generation is not readily detectable. Further tests are necessary in order to establish the identity of this mottled-aleurone pattern. Backcross results from crosses between $V_{13} v_{13}$ and $Pl pl$ will be obtained next year.

Tests of virescent 13 with A a, C c, R r, Sh sh, Wx wx, Pr pr, and Y y

Linkage tests of $V_{13} v_{13}$ with $A a$, $C c$, $R r$, $Sh sh$, $Wx wx$, $Pr pr$, and $Y y$, indicate that $V_{13} v_{13}$ is inherited independently of each of these characters. The detailed data are presented in tables 48, 49, and 51 to 54, and summarized in table 8. Certain indirect evidence (page 20) indicates that possibly $V_{13} v_{13}$ belongs to the same linkage group as $Y y$.

TABLE 8. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_{13} v_{13}$ IS INHERITED INDEPENDENTLY OF $A a$, $C c$, $R r$, $Sh sh$, $Wx wx$, $Pr pr$, AND $Y y$

Genes involved		$V_{13} X^*$	$v_{13} x^*$	$V_{13} x$	$v_{13} X$	Total	$\chi^2 \dagger$	$D \pm \ddagger$		Table in which detailed data are given
$A a, C c, R r$	Observed.....	195	97	238	69	599				48
	Calculated 81:37:111:27	189.53	86.57	259.72	63.18	599	3.7670			
$C c, R r$	Observed.....	27	79	70	28	204				49
	Calculated 1:3:3:1.....	25.5	76.5	76.5	25.5	204	0.9673			
$Sh sh$	Observed.....	203	20	74	65	362				51
	Calculated 9:1:3:3.....	203.625	22.625	67.875	67.875	362	0.9810			
$Wx wx$	Observed.....	84	21	17	91	213		Wx 3.5	wx 2.0	52
	Calculated Wx 1:1, wx 1:1.....	87.5	19	19	87.5	213		± 4.46	± 2.08	
$Pr pr$	Observed.....	187	17	63	63	330				53
	Calculated 9:1:3:3.....	185.625	20.625	61.875	61.875	330	0.6883			
$Y y$	Observed.....	107	20	32	39	198				54
	Calculated 9:1:3:3.....	111.375	12.375	37.125	37.125	198	5.6723			

* X, x = any one of the genes listed under "Genes involved."

† $A \chi^2$ value of 9.0000 for four classes gives odds of 34 to 1.

‡ $A \frac{D}{P.E.}$ value of 3.2 gives odds of 31.36 to 1.

Linkage tests with virescent 14

Linkage of $V_{14} v_{14}$ with $Sh sh Wx wx$

In table 55 is recorded the F_2 -generation progeny of the cross $sh wx V_{14} \times Sh Wx v_{14}$. The segregation of $V_{14} v_{14}$ was determined from seed which had been separated into two classes only, the starchy class and a class including shrunken, waxy, and shrunken-waxy kernels. A segregation

of green and virescent seedlings in a 3:1 ratio is expected in each class. The results recorded in table 55 show a marked deficiency of the crossover classes, indicating a fairly close linkage. The degree of linkage cannot be calculated, since the shrunken and the waxy segregates were not separated.

Test of $V_{14} v_{14}$ with $Su su$

The F_2 progeny of a cross $Su V_{14} \times su v_{14}$ is recorded in table 56. The germination of the sugary seeds was poor; consequently the segregation of $V_{14} v_{14}$ is considered separately in the starchy and sugary classes. In the starchy class the deviation of the observed from the calculated is 8.25 ± 4.28 , and in the sugary class it is 1.25 ± 1.96 . Both deviations are well within the limits of random sampling, thus indicating that $V_{14} v_{14}$ and $Su su$ are inherited independently of each other.

Linkage tests with virescent 15

Linkage of $V_{15} v_{15}$ with $C Sh Wx$

An F_1 ear of the constitution ($a C R V_{15} . A c r v_{15}$) was backcrossed to the triple recessive ($A c r v_{15} . A c r v_{15}$). The results recorded in table 57 give a segregation of 50 green to 9 virescent seedlings in the colored-aleurone class, and 73 green to 99 virescent seedlings in the colorless-aleurone class. These results fit an hypothesis of 12.5 per cent of crossing-over between $V_{15} v_{15}$ and either $C c$ or $R r$.

The F_2 progeny of the cross $sh V_{15} \times Sh v_{15}$ is recorded in table 58. The results, when corrected to compensate for the very poor germination of the shrunken class, give a percentage of crossing-over of 20.

The F_2 progeny of the cross $wx V_{15} \times Wx v_{15}$ is recorded in table 59. The corrected results give a percentage of crossing-over of 19.

The percentage of crossing-over between $Sh sh$ and $Wx wx$ in the seed from which the above progenies came is 20.

From the results presented in tables 57, 58, and 59, it is not possible to decide with certainty the order of the genes, since $Wx wx$ and $Sh sh$ show approximately the same percentage of crossing-over with $V_{15} v_{15}$. Further tests are in progress to determine the order of the genes in this case.

Linkage tests with virescent 17

Linkage of $V_{17} v_{17}$ with $Gl_a gl_a$

The stock of virescent 17 used in these tests was found to be glossy in the seedling stage. When crossed with gl_1 it gave all non-glossy seedlings in the F_1 generation, indicating that $v_{17} gl_a$ is not genetically the same as gl_1 .

The F_2 segregation of glossy and virescent seedlings from the cross $V_{17} Gl_a \times v_{17} gl_a$ is recorded in table 60. The results gave a segregation of 479

green to 21 virescent seedlings in the non-glossy class, and 33 green to 146 virescent seedlings in the glossy class. These results fit an hypothesis of 4.6 per cent of crossing-over.

Tests of $V_{17} v_{17}$ with $A a$, $C c$, $R r$, $Su su$, $Lg lg$, $Y y$, and $Gm gm$

Linkage tests presented in summary in table 9, and in detail in tables 61 to 66, indicate that $V_{17} v_{17}$ is inherited independently of $A a$, $C c$, $R r$, $Su su$, $Lg lg$, $Y y$, and $Gm gm$.

The germless character reported in table 66 is an unknown germless which has not been tested with other known factors for germless.

TABLE 9. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_{17} v_{17}$ IS INHERITED INDEPENDENTLY OF $A a$, $C c$, $R r$, $Su su$, $Lg lg$, $Y y$, AND $Gm gm$

Genes involved		$V_{17} X^*$		$v_{17} x^*$		Total	$\chi^2†$	$D \pm ‡$	Table in which detailed data are given
		$V_{17} X^*$	$v_{17} x^*$	$V_{17} x$	$v_{17} X$				
$C c, R r$	Observed.....	52	68	79	45	244			
	Calculated 3:5:5:3.....	45.75	76.25	76.25	45.75	244	1.8579	.....	61
$A a, C c, R r$	Observed.....	42	35	78	15	170			
	Calculated 81:37:111:27.....	53.79	24.57	73.71	17.93	170	7.7402	.....	62
$Su su$	Observed.....	269	8	57	90	424		Su 0.25 ± 5.53	su 8.25 ± 2.35
	Calculated Su 3:1, su 1:3.....	269.25	16.25	48.75	89.75	424			63
$Lg lg$	Observed.....	34	10	33	12	89			
	Calculated 3:1:3:1.....	33.375	11.125	33.375	11.125	89	0.1985	.....	64
$Y y$	Observed.....	456	40	159	129	784			
	Calculated 9:1:3:3.....	441	49	147	147	784	5.3470	.....	65
$Gm gm$	Observed.....	119	0	0	30	149			
	Calculated 3:1.....	111.75	0	0	37.25	149	....	7.25 ± 3.57	66

* X, x = any one of the genes listed under "Genes involved."

† $A \chi^2$ value of 9.0000 for four classes gives odds of 34 to 1.

‡ $\frac{D}{P.E.}$ value of 3.2 gives odds of 31.36 to 1.

Linkage tests with virescent 18

Linkage of $V_{18} v_{18}$ with $R r$

The progeny of the backcross (mottled aleurone $V_{18} \cdot A C r v_{18}$) $\times$ $A c r v_{18}$ is presented in table 67. The results fit an hypothesis of 20 per cent of crossing-over with either $C c$, $R r$, or the factor causing mottling. Virescent 18 is not linked with $C c$, since results presented in tables 68 and 69 show that $V_{18} v_{18}$ is inherited independently of $Sh sh$ and $Wx wx$. Unfortunately the mottled-aleurone segregates were not separated from the self-colored segregates in the backcrosses given in table 67. In the self-fertilized ears, 2660-1 and 2660-6, in which such a separation was made, the self-colored kernels gave 83 green to 16 virescent seedlings

and the mottled kernels gave 39 green to 5 virescent seedlings, which indicates that $V_{18} v_{18}$ is not linked with the mottling factor. The mottled parent of the original cross was the result of a cross between plants from two mottled kernels, and therefore it is assumed that the mottling factor is blotched ($Bh bh$).

Tests of $V_{18} v_{18}$ with $Sh sh$, $Wx wx$, and $Y y$

Linkage tests between $V_{18} v_{18}$ and $Sh sh$, $Wx wx$, and $Y y$, summarized in table 10, indicate that $V_{18} v_{18}$ is inherited independently of these factors. The detailed data are given in tables 68, 69, and 70.

TABLE 10. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_{18} v_{18}$ IS INHERITED INDEPENDENTLY OF $Sh sh$, $Wx wx$, AND $Y y$

Genes involved		$V_{18} X^*$	$v_{18} x^*$	$V_{18} z$	$v_{18} X$	Total	$D \pm \dagger$	Table in which detailed data are given
$Sh sh$	Total observed.....	78	52	63	54	247		
	Observed combinations..	130		117		247		
	Calculated 1:1.....	123.5		123.5		247	6.5 ± 5.3	68
$Wx wx$	Total observed.....	77	57	64	49	247		
	Observed combinations..	134		113		247		
	Calculated 1:1.....	123.5		123.5		247	10.5 ± 5.3	69
$Y y$	Observed.....	45	7	24	16	92	$\begin{matrix} Y & y \\ 0.75 & 0.75 \end{matrix}$	
	Calculated Y 3:1, y 3:1.	45.75	7.75	23.25	15.25	92	$\begin{matrix} Y & y \\ \pm 2.28 & \pm 1.63 \end{matrix}$	
								70

* X, z = any one of the genes listed under "Genes involved."

† $\frac{D}{A P. E.}$ value of 3.2 gives odds of 31.36 to 1.

Linkage tests with virescent 19

In table 11 are summarized linkage tests made between $V_{19} v_{19}$ and $C c$, $R r$, $Sh sh$, $Wx wx$, $Gh_1 gh_1$, and $Su su$, all of which tests indicate that $V_{19} v_{19}$ is inherited independently of these factors. The detailed data are presented in tables 71 to 76.

Linkage tests with virescent 20

Linkage of $V_{20} v_{20}$ with $R r$

The progeny of a plant of the constitution ($a C R V_{20} . A c r v_{20}$) when crossed with the triple recessive $A c r v_{20}$, is recorded in table 77. The data fit an hypothesis of about 12.5 per cent of crossing-over between either $C c$ or $R r$ and $V_{20} v_{20}$. Results of a cross between $sh V_{20}$ and $Sh v_{20}$, presented in table 78, indicate that $Sh sh$ and $V_{20} v_{20}$ are inherited independently of each other; consequently it is assumed that $V_{20} v_{20}$ is linked with $R r$ with 12.5 per cent of crossing-over.

TABLE 11. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT V_{19} v_{19} IS INHERITED INDEPENDENTLY OF C c , R r , Sh sh , Wx wx , Gh gh , AND Su su

Genes involved		V_{19} X^*	v_{19} x^*	V_{19} x	v_{19} X	Total	χ^2 †	Table in which detailed data are given
C c , R r	Observed.....	270	71	218	80	639		
	Calculated 27:7:21:9.....	269.58	69.89	209.67	89.86	639	1.4311	71
C c , R r	Observed.....	141	85	239	53	518		
	Calculated 9:5:15:3.....	145.69	80.94	242.81	48.56	518	0.8205	72
Sh sh	Observed.....	135	11	35	44	225		
	Calculated 9:1:3:3.....	126.56	14.06	42.19	42.19	225	2.5318	73
Wx wx	Observed.....	138	14	34	41	227		
	Calculated 9:1:3:3.....	127.69	14.19	42.56	42.56	227	2.6139	74
Gh gh	Observed (corrected).....	125	10	35	43	213		
	Calculated 9:1:3:3.....	119.81	13.31	39.94	39.94	213	1.8933	75
Su su	Observed.....	59	5	15	16	95		
	Calculated 9:1:3:3.....	53.44	5.94	17.81	17.81	95	1.3546	76

* X , x = any one of the genes listed under "Genes involved."† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.*Tests of V_{20} v_{20} with Sh sh , Lg lg , Y y , and Su su*

Second-generation progeny of linkage tests, made between V_{20} v_{20} and Sh sh , Lg lg , Y y , and Su su and summarized in table 12, indicate that V_{20} v_{20} is inherited independently of these factors. The detailed data are presented in tables 78 to 81.

TABLE 12. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT V_{20} v_{20} IS INHERITED INDEPENDENTLY OF Sh sh , Lg lg , Y y , AND Su su

Genes involved		V_{20} X^*	v_{20} x^*	V_{20} x	v_{20} X	Total	χ^2 †	D±‡	Table in which detailed data are given
Sh sh	Observed.....	166	7	19	42	234		$\begin{matrix} Sh \\ 10.0 \\ \pm 4.21 \end{matrix}$ $\begin{matrix} sh \\ 0.5 \\ \pm 1.49 \end{matrix}$	78
	Calculated Sh 3:1, sh 3:1.....	156	6.5	19.5	52	234			
Lg lg	Observed.....	529	60	216	177	982			
	Calculated 9:1:3:3.....	552.375	61.375	184.125	184.125	982	6.8138		79
Y y	Observed.....	593	69	168	201	1,031			
	Calculated 9:1:3:3.....	579.94	64.44	193.31	193.31	1,031	4.2365		80
Su su	Observed.....	158	11	37	52	258		$\begin{matrix} Su \\ 0.5 \\ \pm 4.23 \end{matrix}$ $\begin{matrix} su \\ 1.0 \\ \pm 2.02 \end{matrix}$	81
	Calculated Su 3:1, su 3:1.....	157.5	12	36	52.5	258			

* X , x = any one of the genes listed under "Genes involved."† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.‡ A $\frac{D}{P.E.}$ value of 3.2 gives odds of 31.36 to 1.

*Linkage tests with virescent c**Linkage of $V_c v_c$ with $R r$*

The progeny of the cross $\frac{R}{r} \frac{V_c}{v_c} \times \frac{r}{r} \frac{V_c}{v_c}$ (table 83) gives an indication of linkage. The parental classes are much in excess of that expected on the basis of independent inheritance. The percentage of crossing-over which gives the best fit is 37.

Tests of $V_c v_c$ with $C c$, $G_l g_l$, $G_1 g_1$, and $Sh sh$

Linkage tests between $V_c v_c$ and $C c$, $G_l g_l$, $G_1 g_1$, and $Sh sh$, indicate that $V_c v_c$ is inherited independently of these factors. The data are given in detail in tables 82, 84, 85, and 86, and summarized in table 13.

TABLE 13. SUMMARY OF DATA FROM LINKAGE TESTS WHICH INDICATE THAT $V_c v_c$ IS INHERITED INDEPENDENTLY OF $C c$, $G_l g_l$, $G_1 g_1$, AND $Sh sh$

Genes involved		V_c	X^*	v_c	x^*	V_c	x	v_c	X	Total	$\chi^2 \dagger$	$D \pm \ddagger$	Table in which detailed data are given
$C\ c$	Observed.....	61		75		75		64		275			
	Total observed....	136		139		275		275					
	Calculated 1:1.....	137.5		137.5		275		275		.....	1.5 ± 5.59	82	
$G_l\ g_l$	Observed.....	140	14	43	45	242							
	Calculated 9:1:3:3.....	136.125	15.125	45.375	45.375	242	0.3214	.....	84				
$G_1\ g_1$	Observed.....	93	.....	24	36	153							
	Calculated 9:3:4.....	86.06	.....	28.69	38.25	153	1.4588	.....	85				
$Sh\ sh$	Observed.....	156	15	32	44	.....							
	Corrected.....	156	21	44	46	267							
	Calculated 9:1:3:3.....	150.19	16.69	50.06	50.06	267	2.4007	.....	86				

* X, x = any one of the genes listed under "Genes involved."

† A χ^2 value of 9.0000 for four classes gives odds of 34 to 1.

‡ A $\frac{D}{P.E.}$ value of 3.2 gives odds of 31.36 to 1.

*Linkage tests with virescent d**Linkage of $V_d v_d$ with $Gm gm$*

Out of five self-fertilized ears in family 2613, two were found to be segregating for germless seeds. These two ears gave a low percentage of virescent seedlings, the segregation being 402 green to 42 virescent seedlings (table 87, A). The three ears which were not segregating for germless seeds gave green and virescent seedlings in the ratio of 265:98, which is a deviation from a 3:1 ratio of 7.25 ± 5.56 (table 87, B). From these data it is reasonable to assume that $V_d v_d$ is linked with $Gm gm$; but further confirmatory proof, in the form of the repulsion phase of linkage, is necessary in order to verify this assumption. The results recorded in table

87, A, give a perfect fit when calculated on the basis of 15.4 per cent of crossing-over between $V_d v_d$ and $Gm gm$.

Summary of linkage tests

Linkage tests involving the known virescents are summarized in table 14.

TABLE 14. SUMMARY OF LINKAGE TESTS BETWEEN VIRESCENTS AND CHARACTERS IN KNOWN LINKAGE GROUPS, AND OTHER CHARACTERS*

Linkage groups										Other characters				
Virescent	<i>C</i> <i>Sh</i> <i>Wx</i>	<i>L₁</i> <i>R</i> <i>G₁</i>	<i>Su</i> <i>Tu</i>	<i>B</i> <i>Lg</i>	<i>Bh</i> <i>Pl</i> <i>Y</i>	<i>A</i>	<i>Pr</i>	<i>Bn</i> <i>Gh</i>	<i>Cr</i> <i>D₁</i>	<i>Gl_a</i>	<i>Gm</i>	<i>An</i>	<i>L_a</i>	<i>Fl</i>
1	C, Wx							<i>Bn</i>	<i>D₁</i>					
2		<i>L₁ R</i>	<i>Su</i>		<i>Bh, Pl, Y</i>	<i>A</i>	Pr		<i>D₁</i>					
3	<i>Wx</i>	<i>R</i>	<i>Su</i>	<i>Lg</i>	<i>Pl, Y</i>	<i>A</i>	Pr		<i>D₁</i>					
4	C, Wx	<i>R</i>	<i>Su</i>	B, Lg	<i>Y</i>	<i>A</i>		Bn, Gh	<i>D₁</i>					
5					<i>Y</i>									
6					<i>Y</i>									
7														
8			Su, Tu											
9	<i>C, Sh</i>	<i>R</i>	<i>Su</i>		<i>Y</i>									
10						<i>A</i>						<i>An</i>	<i>L_a</i>	
11														
12	<i>Sh</i>		<i>Su</i>	<i>Lg</i>	<i>Y</i>	<i>A</i>	Pr							<i>Fl</i>
13	<i>C, Sh, Wx</i>	<i>R</i>			Bh?	<i>A</i>	Pr							
14	Sh, Wx		<i>Su</i>			<i>A</i>								
15	C, Sh, Wx	<i>R</i>												
16														
17	<i>C</i>	<i>R</i>	<i>Su</i>	<i>Lg</i>	<i>Y</i>	<i>A</i>				<i>Gl_a</i>	<i>Gm</i>			
18	<i>Sh, Wx</i>	R			<i>Y</i>									
19	<i>C, Sh, Wx</i>	<i>R</i>	<i>Su</i>					<i>Gh</i>						
a, b, 20	<i>Sh</i>	R	<i>Su</i>	<i>Lg</i>	<i>Y</i>									
c	<i>C, Sh</i>	R						<i>Gh</i>						
d											Gm			

* Factorial symbols printed in bold-faced type indicate factors that are linked with the particular virescents opposite them in the first column. Italic symbols indicate that the factors concerned are not linked with the corresponding virescents.

The factor pair or pairs with which a particular virescent is linked, the percentage of crossovers, and the worker who reported the linkage, are tabulated on the following page.

DISCUSSION

Virescent seedlings may be arranged in a definite series, ranging from white seedlings, which develop only a small quantity of chlorophyll at ordinary temperatures, to seedlings which are white only at low temperatures and which develop chlorophyll rapidly at normal temperatures. Virescent 8, which does not develop sufficient chlorophyll to supply the plant with carbohydrates, is an example of the former class, and virescent 5, which develops chlorophyll rapidly, is an example of the latter class.

Chlorophyll deficiencies occur exceptionally frequently in maize, and, as a result, such deficiencies have been studied extensively. A list of the chlorophyll deficiencies which have been studied is given in table 15 (page 29).

Virescent	Factor pairs showing linkage with virescents in column 1	Per cent of crosses	Worker*
1.....	<i>C c</i>	30	Demerec (1924)
	<i>Wx wx</i>	7	Demerec (1924)
2.....	<i>Pr pr</i>	41.9	A
3.....	<i>Pr pr</i>	26.8	A
4.....	<i>B b</i>	17	Demerec (1924)
	<i>Lg lg</i>	43	Demerec (1924)
5.....	<i>Bn bn</i>	24.9	Kvakan (1924)
	<i>Gh gh</i>	6.2	Kvakan (1924)
6.....	<i>Y y</i>	23	Carver (1927)
7.....	<i>Y y</i>	38	Carver (1927)
8.....	<i>Su su</i>	33	Demerec (1926)
	<i>Tu tu</i>	<1	A
12.....	<i>Pr pr</i>	12.4	A
13.....	<i>Bh (?)</i>	12	A
14.....	<i>Sh sh Wx wx</i>.....	.....	A
15.....	<i>C c</i>	12.5	A
	<i>Sh sh</i>	20	A
	<i>Wx wx</i>	19	A
17.....	<i>Gla gla</i>	4.6	A
18.....	<i>R r</i>	20	A
20.....	<i>R r</i>	12.5	A

*A=linkage reported in this paper.

Self-fertilization within practically any variety of maize will yield chlorophyll deficiencies. Hutchison (1922 a) found that 28.3 per cent of 1872 self-fertilized ears of maize from seed obtained from 650 different sources were segregating for chlorophyll deficiencies. Hayes and Brewbaker (1924) reported that in a variety of Minnesota No. 13, 39.4 per cent of the first-year self-fertilized lines segregated for chlorophyll deficiencies. The same authors record four probable mutations for seedling chlorophyll deficiencies in 953 selfed lines. This gives a mutation rate of 1 in 238.

SUMMARY

1. A study of twelve Mendelian factors concerned with the development of chlorophyll is reported in this paper. These twelve factor pairs belong to the group of chlorophyll deficiencies known as virescent seedlings, and are designated by the subscript numbers v_9 to v_{20} .

2. Of a total of 142 possible intercrosses between these factors and crosses with virescents 1 to 5 and fine-striped, 138 indicate that these twelve factors are probably genetically different from one another and from virescents 1 to 5 and fine-striped.

3. Virescent 2 is shown to be identical with the virescent studied by Lindstrom (1918).

TABLE 15. CHLOROPHYLL DEFICIENCIES STUDIED

Character	Worker	Number of factors concerned
White seedlings, w_1 to w_{11}	Demerec, 1923 a, 1926 a.....	11
Dominant white seedlings.....	Kempton, 1924.....	1
Xantha seedlings, xn_1 , xn_2	Trajkovich, 1924; Demerec, 1925.....	2
Pale green seedlings, pg_1 to pg_5	Brunson, 1924; Demerec, 1925.....	5
Yellow-green seedlings, yg	Eyster, 1926; Jenkins, 1927.....	2
Virescent seedlings, v_1 to v_{30}	Demerec, 1924; Phipps (this paper).....	20
Yellow-white seedlings m_1 , m_2	Stroman, 1924 b.....	2
Ghost seedlings, gh	Phipps, unpublished.....	1
Golden, g_1 , g_2	Emerson, 1912 b; Lindstrom, 1918; Jenkins, 1926.....	2
White-base leaf, wl	Stroman, 1924 b; Carver, 1927.....	1
Argentia, ar	Eyster, 1926.....	1
Fine-striped, f_1 , f_2	Lindstrom, 1918; Eyster, 1926.....	2
Fine-streaked, fi	Anderson, 1922.....	1
Lineate, li	Collins and Kempton, 1920; Hutchison, 1922 b.....	2
Japonica-striped, j	Emerson, 1912 b; Lindstrom, 1918.....	1
Green-striped, gs	Lindstrom, 1918.....	1
Maternally inherited striping.....	Anderson, 1923; Demerec, 1927.....	1
Ioja striping.....	Jenkins, 1924.....	1
Zebra-striped leaves, zb_1 , zb_2	Demerec, 1921; Stroman, 1924 b.....	2
White sheath.....	Kempton, 1921.....	1
Piebald seedlings, pb_1 to pb_4	Demerec, 1926 b.....	4
Polka-dot leaves, pk	Eyster, 1924.....	1
Blotch leaf, bl	Emerson, 1923.....	1
		65

4. Linkage tests of virescents with other characters in maize indicate the following linkages:

Linked characters	Per cent of crossing-over
$V_2 v_2$ and $Pr pr$	41.9
$V_3 v_3$ and $Pr pr$	26.8
$V_8 v_8$ and $Tu tu$	< 1.0
$V_{12} v_{12}$ and $Pr pr$	12.4
$V_{13} v_{13}$ and $Bh bh$ (?).....	12.0
$V_{14} v_{14}$ and $Sh sh Wx wx$	?
$V_{15} v_{15}$ and $C c$	12.5
$V_{15} v_{15}$ and $Sh sh$	20.0
$V_{15} v_{15}$ and $Wx wx$	19.0
$V_{17} v_{17}$ and $Gl_a gl_a$	4.6
$V_{18} v_{18}$ and $R r$	20.0
$V_{20} v_{20}$ and $R r$	12.5
$V_c v_c$ and $R r$	37.0
$V_d v_d$ and $Gm gm$	15.4

5. A type of behavior which simulates the "balanced lethal" situation in *Drosophila* is reported for maize. Virescent 8, which is a lethal virescent, is very closely linked with the factor pair concerned in the production of tunicate ear (*Tu tu*). Tunicate ear is sterile in the homozygous dominant condition; therefore a plant of the constitution $\frac{v_8 tu}{V_8 Tu}$, when self-fertilized, will produce three genotypes, only one of which is capable of being self-fertilized and of perpetuating the type. This one genotype will be of exactly the same constitution as the parent. The plant of the constitution $\frac{v_8 tu}{V_8 Tu}$ is called a "balanced heterozygote." The one cross-over which was found in a total of 451 individuals is an exception to this behavior.

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APPENDIX

TABLE 16. PROGENY OF THE BACKCROSS ($A V_2 \cdot a v_2$) $\times a v_2$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>A V</i> ₂	<i>a v</i> ₂	<i>A v</i> ₂	<i>a V</i> ₂	
2751B-8 × 2750B.....	58	40	42	45	.....
2750A-10 × 2370.2-9.....	59	48	52	62	.....
Total.....	117	88	94	107	406
Observed.....	205		201		406
Calculated 1:1.....	203		203		406
Difference.....	2 ± 6.80				0

TABLE 17. PROGENY OF THE BACKCROSS ($a V_2 \cdot A v_2$) $\times a v_2$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	A v ₂	a V ₂	A V ₂	a v ₂	
1119B-1 × 1488-3.....	28	32	33	37	.....
1120B-1 × 1499-8.....	80	72	71	69	.....
1120 -5 × 1499-8.....	98	83	101	99	.....
1120 -4 × 1499-8.....	163	122	130	152	.....
1120B-2 × 1499-8.....	67	70	67	57	.....
Total.....	436	379	402	414	1,631
Observed.....	815		816		1,631
Calculated 1:1.....	815.5		815.5		1,631
Difference.....	0.5 ± 13.6				0

TABLE 18. PROGENY OF THE BACKCROSS $\frac{V_2}{v_2} \frac{pr}{Pr} \times \frac{v_2}{v_2} \frac{pr}{pr}$

Pedigree no.	Number of seedlings						Per cent of cross-overs
	Parental combinations		New combinations		Total	Cross-overs	
	$V_2 pr$	$v_2 Pr$	$V_2 Pr$	$v_2 pr$			
2747 -6 × 2740 -2....	62	63	35	43	203	78	.....
2747 -2 × 2743 -2....	31	50	43	29	153	72	.....
2747 -1 × 2742 -3....	31	48	28	31	138	59	.....
2747 × 2743 -2....	13	17	20	18	68	38	.....
2747 -2 × 2367A-9....	37	48	31	25	141	56	.....
2748 -1 × 2367A-9....	44	31	27	28	130	55	.....
2748 × 2740 -1....	59	63	45	42	209	87	.....
2748 -7 × 2367A-9....	43	40	40	42	165	82	.....
2745 -5 × 2742 -3....	41	53	19	24	137	43	.....
1120 -4 × 1499 -8....	23	24	10	12	69	22	.....
1499 -5 × 1120 -5....	53	28	29	31	141	60	.....
1120 -5 × 1499 -8....	40	53	42	20	155	62	.....
1120B-2 × 1499 -8....	22	14	8	21	65	29	.....
Total.....	499	532	377	366	1,774	743	41.9
Observed.....	1,031		743		1,774	.....	.....
Calculated 1:1.....	887		887		1,774	.....	.....
Difference.....	144 ± 14.2				0	.....	.....

TABLE 19. PROGENY OF THE BACKCROSS $\frac{V_2}{v_2} \frac{Pr}{pr} \times \frac{v_2}{v_2} \frac{pr}{pr}$

Pedigree no.	Number of seedlings						Per cent of cross-overs
	Parental combinations		New combinations		Total	Cross-overs	
	$V_2 Pr$	$v_2 pr$	$V_2 pr$	$v_2 Pr$			
2744-1 × 2743-2.....	67	51	41	46	205	.....	.....
Observed.....	118		87		205	87	42.4
Calculated 1:1.....	102.5		102.5		205	.....	.....
Difference.....	15.5 ± 4.83				0	.....	.....

TABLE 20. F_2 PROGENY OF THE CROSS $V_2 \cdot d \times v_2 \cdot D$

Pedigree no.	Number of seedlings				Total
	<i>D</i>		<i>d</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1133-5.....	75	25	29	7	136
Calculated 9:3:3:1.....	76.5	25.5	25.5	8.5	136
	$\chi^2 = 0.7843$				

TABLE 21. F_2 PROGENY OF THE CROSS $V_2 su \times v_2 Su$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2754-3.....	56	19	12	4	.....
1134-5.....	101	31	23	11	.....
Observed.....	157	50	35	15	257
Calculated 3:1, 3:1.....	155.25	51.75	37.5	12.5	257
Difference.....	1.75 ± 4.20		2.5 ± 2.07		0

TABLE 22. PROGENY OF THE CROSS $(A C r V_2 \cdot A C r v_2) \times (A C r V_2 \cdot A c R v_2)$

Pedigree no.	Number of seedlings				Total
	$C R$		$c R$ $C r$ $c r$		
	V	v	V	v	
2759-1 $\times$ 2748-2.....	49	12	32	17	.....
2763-5 $\times$ 2759-1.....	40	15	40	12	.....
Observed.....	89	27	72	29	217
Calculated 3:1:3:1.....	81.375	27.125	81.375	27.125	217
$\chi^2 = 1.9248$					

TABLE 23. F_2 PROGENY OF THE CROSS $V_2 Bh \times v_2 bh$

Pedigree no.	Number of seedlings				
	<i>Bh</i>		<i>bh</i>		Total
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1124-9.....	130	38	35	12	215
Calculated 9:3:3:1.....	120.94	40.31	40.31	13.44	215
	$\chi^2 = 1.6649$				

TABLE 24. PROGENY OF THE BACKCROSS ($Y V_2 \cdot y v_2$) $\times y v_2$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>V Y</i>	<i>v y</i>	<i>V y</i>	<i>v Y</i>	
1120B-2 × 1499-8.....	50	56	50	57	.....
1120 -4 × 1499-8.....	65	81	84	71	.....
Total.....	115	137	134	128	514
Observed.....	252		262		514
Calculated 1:1.....	257		257		514
Difference.....	5 ± 7.65				0

TABLE 25. PROGENY OF THE BACKCROSS $\frac{pr V_3}{Pr v_3} \times \frac{pr v_3}{pr v_3}$

Pedigree no.	Number of seedlings					
	Parental combinations		New combinations		Total	Cross-overs
	$V_3 pr$	$v_3 Pr$	$V_3 Pr$	$v_3 pr$		Per cent of cross-overs
2804-2 $\times$ 2806A-3.....	50	78	23	19	.....	42
2804-1 $\times$ 2803 -1.....	50	59	23	10	.....	33
2804-6 $\times$ 2803 -2.....	58	51	16	10	.....	26
2805-4 $\times$ 2803 -1.....	54	43	14	22	.....	36
2805-2 $\times$ 2803 -1.....	52	61	26	23	.....	49
2806E $\times$ 2806A-3.....	32	28	21	18	.....	39
Total.....	296	320	123	102	841	.....
Observed.....	616		225		841	225
						26.8

TABLE 26. PROGENY OF THE BACKCROSS $(V_3 d_1 . v_3 D_1) \times v_3 d_1$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	$V_3 d_1$	$v_3 D_1$	$V_3 D_1$	$v_3 d_1$	
1142-2 $\times$ 1503-1.....	57	56	63	47	.....
1142-1 $\times$ 1503-1.....	55	56	54	47	.....
Total.....	112	112	117	94	435
Observed.....	224		211		435
Calculated 1:1.....	217.5		217.5		435
Difference.....	6.5 $\pm$ 7.03				0

0

TABLE 27. PROGENY OF THE BACKCROSS ($V_3 Su . v_3 su$) $\times$ $v_3 su$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	$V_3 Su$	$v_3 su$	$V_3 su$	$v_3 Su$	
1142-1 $\times$ 1503-1.....	85	60	75	81	.....
Observed.....	145		156		301
Calculated 1:1.....	150.5		150.5		301
Difference.....	5.5 $\pm$ 5.85				0

TABLE 28. PROGENY OF THE BACKCROSS ($V_3 pl . v_3 Pl$) $\times$ $v_3 pl$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	$V_3 pl$	$v_3 Pl$	$V_3 Pl$	$v_3 pl$	
1143 3 $\times$ 1020B 2.....	24	24	28	23	.....
Observed.....	48		51		99
Calculated 1:1.....	49.5		49.5		99
Difference.....	1.5 $\pm$ 3.36				0

TABLE 29. PROGENY OF THE CROSS ($V_3 Y . v_3 y$) $\times$ ($v_3 Y . v_3 y$)

Pedigree no.	Number of seedlings				Total
	Y		y		
	V ₃	v ₃	V ₃	v ₂	
1142-4 × 1503-1.....	65	64	25	24	178
Calculated 3:3:1:1.....	66.75	66.75	22.25	22.25	178

$$\chi^2 = 0.6367$$

TABLE 30. F₂ PROGENY OF THE CROSS $\frac{Su}{Su} \frac{V_s}{V_s} \frac{T_u}{t_u} \times \frac{su}{su} \frac{V_s}{v_s} \frac{tu}{tu}$

Pedigree no.		Number of mature plants				Total
1926 (Emerson)	1927	<i>Su</i>		<i>su</i>		
		<i>Tu</i>	<i>tu</i>	<i>Tu</i>	<i>tu</i>	
A. Segregation of <i>Su su</i> and <i>Tu tu</i> in families which are segregating for <i>V_s v_s</i>						
17450-2.....	3200	80	0	17	0	.....
17450-3a.....	3201	21	0	6	0	.....
17451-2.....	3202	85	0	17	0	.....
Observed.....		186	0	40	0	226
B. Segregation of <i>Su su</i> and <i>Tu tu</i> in families which are not segregating for <i>V_s v_s</i>						
17450-9.....	3210	114	27	28	14	.....
17451-1.....	3211	84	18	14	11	.....
Observed.....		198	45	42	25	310

TABLE 31. F₂ PROGENY OF THE CROSS $\frac{Su}{Su} \frac{V_s}{v_s} \frac{tu}{tu} \times \frac{su}{su} \frac{V_s}{V_s} \frac{T_u}{t_u}$

Pedigree no.		Number of mature plants				
1926 (Emerson)	1927	<i>Su</i>		<i>su</i>		Total
		<i>Tu</i>	<i>tu</i>	<i>Tu</i>	<i>tu</i>	
A. Segregation of <i>Su su</i> and <i>Tu tu</i> in families which are segregating for <i>V_s v_s</i>						
17452-1.....	3203	92	0	34	0	.....
17452-6.....	3204	50	0	14	1	.....
17453-2.....	3206	21	0	13	0	.....
Observed.....		163	0	61	1	225
B. Segregation of <i>Su su</i> and <i>Tu tu</i> in families which are not segregating for <i>V_s v_s</i>						
17452-4.....	3212	79	29	28	6	.....
17453-1.....	3213	9	2	2	1	.....
17453-3.....	3214	21	7	2	3	.....
17453-5.....	3215	58	20	11	2	.....
17453-7.....	3216	8	3	0	0	.....
17453-6.....	3217	22	10	6	1	.....
Observed.....		197	71	49	13	330

TABLE 32. PROGENY OF THE CROSS (*A c R Pr sh wx V₉* . *A C r Pr Sh Wx v₉*) × *A c r sh wx V₉ v₉*

Pedigree no.	Number of seedlings				Total
	<i>Sh</i>		<i>sh</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2588-2 × 2588.1-1.....	72	16	66	22	176
Calculated 3:1:3:1.....	66	22	66	22	176
	$\chi^2 = 2.1819$				

TABLE 33. PROGENY OF THE CROSS (*A c R V₉* . *A C r v₉*) × (*A c r V₉* . *A c r v₉*)

Pedigree no.	Number of seedlings				Total
	<i>C R</i>		<i>C r, c R,</i> and <i>c r</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2588-2 × 2588.1-1.....	34	8	104	30	176
Calculated 3:1:9:3.....	33	11	99	33	176

TABLE 34. PROGENY OF THE BACKCROSS (*A c R[±] V₉* . *A C r[±] v₉*) × *A r[±] v₉*

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>V R^s</i>	<i>v R^r</i>	<i>V R^r</i>	<i>v R^s</i>	
2588 -3 × 2405B-2.....	13	15	13	14	.....
2405C-7 × 2405B-6.....	15	16	15	12	.....
Total.....	28	31	28	26	113
Observed.....	59		54		113
Calculated 1:1.....	56.5		56.5		113
Difference.....	2.5 ± 3.58				0

TABLE 35. F_2 PROGENY OF THE CROSS $V_9 y \times v_9 Y$

Pedigree no.	Number of seedlings				Total
	<i>Y</i>		<i>y</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2657-1.....	34	18	14	5	.....
2657-4.....	30	13	12	4	.....
Observed.....	64	31	26	9	130
Calculated 9:3:3:1.....	73.125	24.375	24.375	8.125	130
$\chi^2 = 3.1418$					

TABLE 36. F_2 PROGENY OF THE CROSS $V_9 su \times v_9 Su$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2588-2.....	32	12	19	4	.....
2588-4.....	42	17	17	3	.....
2588-8.....	70	19	6	1	.....
Observed.....	144	48	42	8	242
Calculated 3:1, 3:1.....	144	48	37.5	12.5	242
Difference.....	0 ± 4.05		4.5 ± 2.07		0

TABLE 37. F_2 PROGENY OF THE CROSS $v_{10} An \times V_{10} an$

Pedigree no.	Number of seedlings				Total
	<i>An</i>		<i>an</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1176-2.....	154	51	49	18	.....
1176-3.....	71	42	29	16	.....
1176-5.....	59	21	19	3	.....
1176-6.....	94	25	35	4	.....
1176-7.....	104	42	35	12	.....
Observed.....	482	181	167	53	883
Calculated 9:3:3:1.....	496.69	165.56	165.56	55.19	883
	$\chi^2 = 1.9738$				

TABLE 38. F_2 PROGENY OF THE CROSS $V_{10} a \times v_{10} A$

Pedigree no.	Number of seedlings				Total
	<i>A</i>		<i>a</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1176-6.....	99	20	39	9	158
Calculated 9:3:3:1.....	88.875	29.625	29.625	9.875	158
$\chi^2 = 6.1856$					

TABLE 39. F_2 PROGENY OF THE CROSS $V_{10} l \times v_{10} L$

Pedigree no.	Number of seedlings				Total
	V		v		
	L	l	L	l	
1176-2.....	229		53	20	.....
1176-6.....	129		24	5	.....
Observed.....	358		77	25	460
Calculated 12:3:1.....	345		86.25	28.75	460
$\chi^2 = 1.9710$					

TABLE 40. F₂ PROGENY OF THE CROSS $\frac{V_{12} Pr}{v_{12} pr}$

Pedigree no.	Number of seedlings					
	<i>Pr</i>		<i>pr</i>		Total	Per cent of cross-overs
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>		
2590-3 × 2590-1.....	61	5	2	20	.....	.....
2590-10 × 2590-8.....	85	3	3	27	.....	.....
2590-2.....	73	6	4	22	.....	.....
2590-6.....	36	1	2	20	.....	.....
2590-8.....	69	8	5	18	.....	.....
2594A-2.....	81	6	11	8	.....	.....
2594-3.....	52	5	4	12	.....	.....
2421C × 2596-2.....	35	3	8	10	.....	.....
Observed.....	492	37	39	137	705	11.4

TABLE 41. PROGENY OF THE BACKCROSS $\frac{V_{12} Pr}{v_{12} pr} \times \frac{v_{12} pr}{v_{12} pr}$

Pedigree no.	Number of seedlings						
	Parental combinations		New combinations		Total	Cross-overs	Per cent of cross-overs
	<i>V Pr</i>	<i>v pr</i>	<i>V pr</i>	<i>v Pr</i>			
2590 -1 × 2594.1A-1...	38	44	3	1	.....	4	.....
2594A-1 × 2594.1A-4...	11	16	0	3	.....	3	.....
2594A-5 × 2594.1A-4...	12	13	1	11	.....	12	.....
Total.....	61	73	4	15	153	19	.....
Observed.....	134		19		153	19	12.4

TABLE 42. F_2 PROGENY OF THE CROSS $V_{12} sh \times v_{12} Sh$

Pedigree no.	Number of seedlings				Total
	<i>Sh</i>		<i>sh</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2590- 3 × 2590-1.....	89	30	17	9	.....
2590-10 × 2590-8.....	122	42	15	4	.....
2590- 2.....	115	33	15	2	.....
2590- 6.....	54	31	18	4	.....
2590- 8.....	99	34	16	4	.....
Observed.....	479	170	81	23	753
Calculated 3:1, 3:1.....	486.75	162.25	78	26	753
Difference.....	7.75 ± 7.44		3.0 ± 2.98		0

TABLE 43. F_2 PROGENY OF THE CROSS $V_{12} su \times v_{12} Su$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2421E-26 × 2421D-1.....	71	24	32	7	.....
2421E-19.....	59	17	15	5	.....
2421-4.....	47	18	10	5	.....
2421E-21.....	50	12	16	10	.....
2594-3.....	76	27	19	12	.....
2594B-3.....	61	16	11	4	.....
Observed.....	364	114	103	43	624
Calculated 9:3:3:1.....	351	117	117	39	624
$\chi^2 = 2.6439$					

TABLE 44. F₂ PROGENY OF THE CROSS $V_{12} Y \times v_{12} y$

Pedigree no.	Number of seedlings				Total
	Y		y		
	V	v	V	v	
2594-3.....	37	13	14	5	69
Calculated 9:3:3:1.....	38.81	12.94	12.94	4.31	69
$\chi^2 = 0.2820$					

TABLE 45. F₂ PROGENY OF THE CROSS V_{12} FLOURY $\times$ v_{12} FLINTY

Pedigree no.	Number of seedlings				Total
	Floury		Flinty		
	V	v	V	v	
2593-1.....	46	18	44	18	126
Calculated 3:1:3:1.....	47.25	15.75	47.25	15.75	126
$\chi^2 = 0.8994$					

TABLE 46. F₂ PROGENY OF THE CROSS $V_{12} lg \times v_{12} Lg$

Pedigree no.	Number of seedlings				
	<i>Lg</i>		<i>lg</i>		Total
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2592-1.....	38	12	11	6	.....
2592-2.....	39	16	15	4	.....
2592-5.....	54	26	11	4	.....
2592-6.....	48	12	23	5	.....
2592-9.....	48	10	15	6	.....
Observed.....	227	76	75	25	403
Calculated 9:3:3:1.....	226.69	75.56	75.56	25.19	403
$\chi^2 = 0.0086$					

TABLE 47. PROGENY OF THE BACKCROSS ($v_{12} A . V_{12} a$) $\times v_{12} a$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>V a</i>	<i>v A</i>	<i>V A</i>	<i>v a</i>	
2594 - 5 × 2594.1A-4.....	35	39	38	34	.....
2421E-25 × 2594.1A-5.....	33	24	27	25	.....
Total.....	68	63	65	59	.....
Observed.....	131		124		255
Calculated 1:1.....	127.5		127.5		255
Difference.....	3.5 ± 5.39				0

TABLE 48. F_2 PROGENY OF THE CROSS $a C R V_{13} \times A c r v_{13}$

Pedigree no.	Number of seedlings				Total
	Colored		Colorless		
	V	v	V	v	
1185-1.....	30	10	42	14	.....
1185-2.....	34	11	43	17	.....
1185-4.....	30	12	34	14	.....
1185-6.....	43	9	39	19	.....
2704-3.....	25	10	29	8	.....
2704-4.....	33	17	51	25	.....
Observed.....	195	69	238	97	599
Calculated 81:27:111:37.....	189.53	63.18	259.72	86.57	599
	$\chi^2 = 3.7670$				

TABLE 49. PROGENY OF THE BACKCROSS ($C R V_{13} \cdot c r v_{13}$) $\times$ $c r v_{13}$

Pedigree no.	Number of seedlings				Total
	$C R$		$C r, c R,$ and $c r$		
	V	v	V	v	
2704-5 $\times$ 2424-2.....	27	28	70	79	204
Calculated 1:1:3:3.....	25.5	25.5	76.5	76.5	204
$\chi^2 = 0.9673$					

TABLE 50. F_2 PROGENY OF THE CROSS $A B h V_{13} \times A c r b h v_{13}$

Pedigree no.	Number of seedlings				
	Blotched		Colorless		Total
	V	v	V	v	
2646-3.....	62	1	32	21	.....
2646-3 duplicate planting.....	36	2	15	10	.....
Observed.....	98	3	47	31	179

TABLE 51. F_2 PROGENY OF THE CROSS $V_{13} sh \times v_{13} Sh$

Pedigree no.	Number of seedlings				Total
	<i>Sh</i>		<i>sh</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1184-5.....	78	33	42	10	.....
1184-6.....	58	15	10	5	.....
2429-1.....	67	17	22	5	.....
Observed.....	203	65	74	20	362
Calculated 9:3:3:1.....	203.625	67.875	67.875	22.625	362
$\chi^2 = 0.9810$					

TABLE 52. PROGENY OF THE CROSS ($V_{13} wx . v_{13} Wx$) $\times$ ($v_{13} Wx . v_{13} wx$)

Pedigree no.	Number of seedlings				Total
	<i>Wx</i>		<i>wx</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2703-5 × 2426-7.....	52	57	12	10	.....
2429-2 × 2429-1.....	32	34	5	11	.....
Observed.....	84	91	17	21	213
Calculated 1:1, 1:1.....	87.5	87.5	19	19	213
Difference.....	3.5 ± 4.46		2.0 ± 2.08		0

TABLE 53. F_2 PROGENY OF THE CROSS $V_{13} pr \times v_{13} Pr$

Pedigree no.	Number of seedlings				Total
	<i>Pr</i>		<i>pr</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2704-2.....	35	14	15	3	.....
2704-3.....	16	8	8	2	.....
2704-4.....	25	8	14	3	.....
1185-1.....	23	10	7	0	.....
1185-2.....	30	9	4	2	.....
1185-4.....	25	7	5	5	.....
1185-6.....	33	7	10	2	.....
Observed.....	187	63	63	17	330
Calculated 9:3:3:1.....	185.625	61.875	61.875	20.625	330
$\chi^2 = 0.6883$					

TABLE 54. F₂ PROGENY OF THE CROSS $V_{13} y \times v_{13} Y$

Pedigree no.	Number of seedlings				Total
	Y		y		
	V	v	V	v	
1185-1.....	25	8	7	6	.....
1185-2.....	33	11	10	6	.....
1185-4.....	22	9	8	2	.....
1185-6.....	27	11	7	6	.....
Observed.....	107	39	32	20	198
Calculated 9:3:3:1.....	111.375	37.125	37.125	12.375	198
$\chi^2 = 5.6723$					

TABLE 55. F₂ PROGENY OF THE CROSS $V_{14} sh wx \times v_{14} Sh Wx$

Pedigree no.	Number of seedlings				Total
	<i>Sh Wx</i>		<i>Sh wx, sh Wx,</i> and <i>sh wx</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2598-7.....	46	28	35	6	.....
2598-4.....	39	24	33	4	.....
Observed.....	85	52	68	10	215

TABLE 56. F₂ PROGENY OF THE CROSS $V_{14} Su \times v_{14} su$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2598-7.....	81	34	14	2	.....
2598-4.....	72	28	21	8	.....
Observed.....	153	62	35	10	260
Calculated 3:1, 3:1.....	161.25	53.75	33.75	11.25	260
Difference.....	8.25 ± 4.28		1.25 ± 1.96		0

TABLE 57. PROGENY OF THE CROSS ($a C R V_{15} \cdot A c r v_{15}$) $\times A c r v_{15}$

Pedigree no.	Number of seedlings					
	$C R$		$C r, c R,$ and $c r$		Total	Per cent of cross- overs
	V	v	V	v		
2601-1 $\times$ 2444A-15.....	14	5	18	27	.....	.....
2604-7 $\times$ 2444A- 8.....	36	4	55	72	.....	.....
Observed.....	50	9	73	99	231	.....
Calculated 7:1:9:15.....	50.53	7.22	64.97	108.28	231	12.5

TABLE 58. F_2 PROGENY OF THE CROSS $sh V_{15} \times Sh v_{15}$

Pedigree no.	Number of seedlings					
	Sh		sh		Total	Per cent of cross- overs
	V	v	V	v		
2706-2.....	51	20	7	0	.....	.....
1189-1.....	62	43	19	1	.....	.....
1189-2.....	84	33	27	0	.....	.....
1189-5.....	77	39	17	1	.....	.....
1189-7.....	92	36	3	0	.....	.....
Observed.....	366	171	73	2	.....	.....
Corrected.....	366	171	172	5	714	20

TABLE 59. F_2 PROGENY OF THE CROSS $wx V_{15} \times Wx v_{15}$

Pedigree no.	Number of seedlings					
	Wx		wx		Total	Per cent of cross- overs
	V	v	V	v		
2706-2.....	48	20	10	0	.....	.....
1189-2.....	89	32	22	1	.....	.....
1189-5.....	75	40	19	0	.....	.....
1189-7.....	85	36	10	0	.....	.....
Observed.....	297	128	61	1	.....	.....
Corrected.....	297	128	139	2	566	19

TABLE 60. F_2 PROGENY OF THE CROSS $V_{17} Gl_a \times v_{17} gl_a$

Pedigree no.	Number of seedlings					
	Gl_a		gl_a		Total	Per cent of cross-overs
	V	v	V	v		
1167-5.....	160	8	2	46	.....	.....
1167-6.....	91	1	8	22	.....	.....
1167-7.....	98	7	0	32	.....	.....
1167-9.....	92	1	8	27	.....	.....
1195-4.....	38	4	15	19	.....	.....
Observed.....	479	21	33	146	679	4.6

TABLE 61. F_2 PROGENY OF THE CROSS $(A C R Pr V_{17} . A c r Pr v_{17}) \times A v_{17}$

Pedigree no.	Number of seedlings				Total
	$C R$		$C r, c R,$ and $c r$		
	V	v	V	v	
2605-5 $\times$ 2605.2-3.....	24	30	48	34	.....
2605-1 $\times$ 2455A-6.....	28	15	31	34	.....
Observed.....	52	45	79	68	244
Calculated 3:3:5:5.....	45.75	45.75	76.25	76.25	244
$\chi^2 = 1.8579$					

TABLE 62. F_2 PROGENY OF THE CROSS $a C R Pr V_{17} \times A c r Pr v_{17}$

Pedigree no.	Number of seedlings				
	Colored		Colorless		Total
	V	v	V	v	
2609-1.....	24	11	45	19	.....
2609-4 × 2609-3.....	18	4	33	16	.....
Observed.....	42	15	78	35	170
Calculated 81:27:111:37.....	53.79	17.93	73.71	24.57	170
$\chi^2 = 7.7402$					

TABLE 63. F_2 PROGENY OF THE CROSS $Su V_{17} \times Su v_{17}$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1167-6.....	84	22	15	1	.....
1167-9.....	91	25	9	4	.....
2609-1.....	50	29	19	1	.....
2709-6.....	44	14	14	2	.....
Observed.....	269	90	57	8	424
Calculated 3:1, 3:1.....	269.25	89.75	48.75	16.25	424
Difference.....	0.25 ± 5.53		8.25 ± 2.35		0

TABLE 64. PROGENY OF THE CROSS $(lg V_{17} \cdot Lg v_{17}) \times (lg V_{17} \cdot lg v_{17})$

Pedigree no.	Number of seedlings				Total
	<i>Lg</i>		<i>lg</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2647-2 × 2647.1-2.....	34	12	33	10	89
Calculated 3:1:3:1.....	33.375	11.125	33.375	11.125	89
$\chi^2 = 0.1985$					

TABLE 65. F_2 PROGENY OF THE CROSS $Y V_{17} \times y v_{17}$

Pedigree no.	Number of seedlings				Total
	Y		y		
	V	v	V	v	
1167-3.....	109	31	33	12	.....
1167-5.....	121	32	41	14	.....
1167-9.....	60	25	31	4	.....
1173-1.....	30	6	8	1	.....
1173B-3.....	74	15	25	3	.....
2709-5.....	62	20	21	6	.....
Observed.....	456	129	159	40	784
Calculated 9:3:3:1.....	441	147	147	49	784

$\chi^2 = 5.3470$

TABLE 66. PROGENY OF A PLANT OF THE CONSTITUTION $V_{17} v_{17} Gm gm$

Pedigree no.	Number of seedlings				Total
	V		v		
	Gm	gm	Gm	gm	
2453A-3.....	119	.....	30	.....	149
Calculated 3:1.....	111.75	.....	37.25	.....	149
Difference.....	7.25 ± 3.57				0

TABLE 67. PROGENY OF THE BACKCROSS (MOTTLED ALEURONE $V_{18} \cdot A Cr v_{18}$) $\times A Cr v_{18}$

Pedigree no.	Number of seedlings					
	Colored		Colorless		Total	Per cent of cross-overs
	V	v	V	v		
2660-3 × 2476 -7.....	25	7	22	40	.....	.....
2660-5 × 2476A-2.....	26	8	21	53	.....	.....
Observed.....	51	15	43	93	202	.....
Calculated 12:3:8:17.....	60.60	15.15	40.40	85.85	202	20

TABLE 68. PROGENY OF THE BACKCROSS ($sh V_{18} \times Sh v_{18}$) $\times sh v_{18}$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>V sh</i>	<i>v Sh</i>	<i>V Sh</i>	<i>v sh</i>	
2615-1 × 2615.1-4.....	22	26	26	13	.....
2615-2 × 2615.2-3.....	41	28	52	39	.....
Total.....	63	54	78	52	247
Observed.....	117		130		247
Calculated 1:1.....	123.5		123.5		247
Difference.....	6.5 ± 5.30				0

TABLE 69. PROGENY OF THE BACKCROSS ($wx V_{18} \cdot Wx v_{18}$) $\times wx v_{18}$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>V wx</i>	<i>v Wx</i>	<i>V Wx</i>	<i>v wx</i>	
2615-1 × 2615.1-4.....	22	25	26	14	.....
2615-2 × 2615.2-3.....	42	24	51	43	.....
Total.....	64	49	77	57	247
Observed.....	113		134		247
Calculated 1:1.....	123.5		123.5		247
Difference.....	10.5 ± 5.30				0

TABLE 70. F_2 PROGENY OF THE CROSS $y V_{18} \times Y v_{18}$

Pedigree no.	Number of seedlings				Total
	<i>V</i>		<i>v</i>		
	<i>Y</i>	<i>y</i>	<i>Y</i>	<i>y</i>	
2615-5.....	45	16	24	7	92
Calculated 3:1, 3:1.....	45.75	15.25	23.25	7.75	92
Difference.....	0.75 ± 2.28		0.75 ± 1.63		0

TABLE 71. F_2 PROGENY OF THE CROSS $A c R V_{19} \times A C r v_{19}$

Pedigree no.	Number of seedlings				Total
	<i>C R</i>		<i>C r, c R, and c r</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2617B-2.....	43	17	31	9	.....
2618 -2.....	46	17	35	11	.....
2623A-1.....	63	13	43	15	.....
2623A-2.....	63	20	60	17	.....
2623B-2.....	55	13	49	19	.....
Observed.....	270	80	218	71	639
Calculated 27:9:21:7.....	269.58	89.86	209.67	69.89	639
$\chi^2 = 1.4311$					

TABLE 72. PROGENY OF THE CROSS $A c R V_{19} \cdot A C r v_{19} \times A C r v_{19} \cdot A c r v_{19}$

Pedigree no.	Number of seedlings				
	$C R$		$C r, c R, \text{ and } c r$		Total
	V	v	V	v	
2617B-1 $\times$ 2617A-2.....	28	13	49	21	.....
2658A-1 $\times$ 2658A-4.....	37	12	54	15	.....
2658A-1 $\times$ 2658B-2.....	44	14	64	30	.....
2658B-4 $\times$ 2658A-1.....	32	14	72	19	.....
Observed.....	141	53	239	85	518
Calculated 9:3:15:5.....	145.69	48.56	242.81	80.94	518
$\chi^2 = 0.8205$					

TABLE 73. F_2 PROGENY OF THE CROSS $sh V_{19} \times Sh v_{19}$

Pedigree no.	Number of seedlings				Total
	<i>Sh</i>		<i>sh</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2618-2.....	63	22	16	6	.....
2658A-1 × 2658B-4.....	72	22	19	5	.....
Observed.....	135	44	35	11	225
Calculated 9:3:3:1.....	126.56	42.19	42.19	14.06	225
$\chi^2 = 2.5318$					

TABLE 74. F_2 PROGENY OF THE CROSS $wx V_{19} \times Wx v_{19}$

Pedigree no.	Number of seedlings				Total
	Wx		wx		
	V	v	V	v	
2618-2.....	67	21	14	7	.....
2658A-1 $\times$ 2658B-4.....	71	20	20	7	.....
Observed.....	138	41	34	14	227
Calculated 9:3:3:1.....	127.69	42.56	42.56	14.19	227
$\chi^2 = 2.6139$					

TABLE 75. F_2 PROGENY OF THE CROSS $gl_1 V_{19} \times Gl_1 v_{19}$

Pedigree no.	Number of seedlings				Total
	<i>Gl</i>		<i>gl</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2621-2.....	96	20	24	5	.....
2621-3.....	29	9	11	2	.....
Observed.....	125	29	35	7	.....
Corrected.....	125	43	35	10	213
Calculated 9:3:3:1.....	119.81	39.94	39.94	13.31	213
$\chi^2 = 1.8933$					

TABLE 76. F_2 PROGENY OF THE CROSS $Su V_{19} \times Su v_{19}$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2625.1B-5.....	59	16	15	5	95
Calculated 9:3:3:1.....	53.44	17.81	17.81	5.94	95
$\chi^2 = 1.3546$					

TABLE 77. PROGENY OF THE BACKCROSS $a C R V_{20} \cdot A c r v_{20} \times A c r v_{20}$

Pedigree no.	Number of seedlings					Per cent of cross-overs
	<i>C R</i>		<i>C r, c R, and c r</i>		Total	
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>		
2639-1 × 2508-1.....	41	6	42	78	.....	.....
2639-5 × 2508-4.....	36	4	38	74	.....	.....
Observed.....	77	10	80	152	319	.....
Calculated 7:1:9:15.....	69.78	9.97	89.72	149.53	319	12.5

TABLE 78. F₂ PROGENY OF THE CROSS *sh V*₂₀ × *Sh v*₂₀

Pedigree no.	Number of seedlings				Total
	<i>Sh</i>		<i>sh</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2645-1.....	89	15	14	6	.....
2645-7.....	77	27	5	1	.....
Observed.....	166	42	19	7	234
Calculated 3:1, 3:1.....	156	52	19.5	6.5	234
Difference.....	10.0 ± 4.21		0.5 ± 1.49		0

TABLE 79. F₂ PROGENY OF THE CROSS *lg V*₂₀ × *Lg v*₂₀

Pedigree no.	Number of seedlings				Total
	<i>Lg</i>		<i>lg</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
1208-2.....	93	17	32	7	.....
1208-3.....	95	33	43	8	.....
1290-2.....	129	48	63	13	.....
1290-3.....	97	39	33	11	.....
1290-4.....	115	40	45	21	.....
Observed.....	529	177	216	60	982
Calculated 9:3:3:1.....	552.375	184.125	184.125	61.375	982
$\chi^2 = 6.8138$					

TABLE 80. F_2 PROGENY OF THE CROSS $y V_{20} \times Y v_{20}$

Pedigree no.	Number of seedlings				Total
	Y		y		
	V	v	V	v	
2511C-8.....	49	17	9	7	.....
1209 -2.....	141	55	51	6	.....
1209 -3.....	102	34	28	16	.....
1209 -4.....	125	40	35	21	.....
2641 -2.....	63	10	12	8	.....
2641 -4.....	49	22	15	6	.....
2641 -7.....	64	23	18	5	.....
Observed.....	593	201	168	69	1,031
Calculated 9:3:3:1.....	579.94	193.31	193.31	64.44	1,031

$\chi^2 = 4.2365$

TABLE 81. F_2 PROGENY OF THE CROSS $su V_{20} \times Su v_{20}$

Pedigree no.	Number of seedlings				Total
	<i>Su</i>		<i>su</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2641-2.....	58	16	17	2	.....
2641-3.....	48	15	8	2	.....
2641-4.....	52	21	12	7	.....
Observed.....	158	52	37	11	258
Calculated 3:1, 3:1.....	157.5	52.5	36	12	258
Difference.....	0.5 ± 4.23		1.0 ± 2.02		0

TABLE 82. PROGENY OF THE BACKCROSS $C c V_c v_c \times c v_c$

Pedigree no.	Number of seedlings				Total
	Parental combinations		New combinations		
	<i>V c</i>	<i>v C</i>	<i>V C</i>	<i>v c</i>	
1069B-1 × 1069A-10.....	22	21	19	19	.....
1069A-9 × 1069B- 7.....	24	25	23	30	.....
2458C-5 × 2458B- 2.....	29	18	19	26	.....
Total.....	75	64	61	75	.....
Observed.....	139		136		275
Calculated 1:1.....	137.5		137.5		275
Difference.....	1.5 ± 5.59				0

TABLE 83. PROGENY OF THE CROSS $R V_c . r v_c \times r V_c . r v_c$

Pedigree no.	Number of seedlings					Per cent of cross-overs
	$V R$	$v r$	$V r$	$v R$	Total	
2611A-2 $\times$ 2611B-2.....	41	15	28	9	.....	.....
2611B-1 $\times$ 2611A-2.....	40	21	34	5	.....	.....
2611B-1 $\times$ 2611A-2.....	40	15	27	10	.....	.....
Observed.....	121	51	89	24	285	37

TABLE 84. F_2 PROGENY OF THE CROSS $gl_1 V_c \times Gl_1 v_c$

Pedigree no.	Number of seedlings				Total
	<i>Gl</i>		<i>gl</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2611A-2 × 2611B-2.....	50	20	19	4	.....
2611B-1 × 2611A-2.....	90	25	24	10	.....
Observed.....	140	45	43	14	242
Calculated 9:3:3:1.....	136.125	45.375	45.375	15.125	242
$\chi^2 = 0.3214$					

TABLE 85. F_2 PROGENY OF THE CROSS $g_1 V_c \times G_1 v_c$

Pedigree no.	Number of seedlings			
	V		v	Total
	G	g	$G + g$	
2611A-2 $\times$ 2611B-2.....	41	9	11	.....
2611B-1 $\times$ 2611A-2.....	52	15	25	.....
Observed.....	93	24	36	153
Calculated 9:3:4.....	86.06	28.69	38.25	153
$\chi^2 = 1.4588$				

TABLE 86. F_2 PROGENY OF THE CROSS $sh V_c \times Sh v_c$

Pedigree no.	Number of seedlings				Total
	<i>Sh</i>		<i>sh</i>		
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>	
2650-1.....	36	9	4	4	.....
2650-2.....	84	24	23	7	.....
2650-3.....	36	11	5	4	.....
Observed.....	156	44	32	15	.....
Corrected.....	156	46	44	21	267
Calculated 9:3:3:1.....	150.19	50.06	50.06	16.69	267
$\chi^2 = 2.4007$					

TABLE 87. F₂ PROGENY OF PLANTS OF THE CONSTITUTION *Gm Vd . gm vd*

Pedigree no:	Number of seedlings					
	<i>Gm</i>		<i>gm</i>		Total	Per cent of cross-overs
	<i>V</i>	<i>v</i>	<i>V</i>	<i>v</i>		
A. Segregation of virescent seedlings in families segregating for germless						
2613-3.....	179	12	0	0	.....	.....
2613-6.....	223	30	0	0	.....	.....
Observed.....	402	42	0	0	444	.....
Calculated 5.5:1:1:5.5 gametic ratio.....	402	42	.....	.....	444	15.4
B. Segregation of virescent seedlings in families not segregating for germless						
2613-2.....	151	57	.....	.....	.....	.....
2613-7.....	59	26	.....	.....	.....	.....
2613-8.....	55	15	.....	.....	.....	.....
Observed.....	265	98	.....	.....	363	.....
Calculated 3:1.....	272.25	90.75	.....	.....	363	.....
Difference.....	7.25 ± 5.56		.....	.....	0	.....

Memoir 122, *The Effect of Freezing on the Catalase Activity of Apple Fruits*, the third preceding number in this series of publications, was mailed on May 3, 1929.

Memoir 123, *Three Rust Diseases of the Apple*, was mailed on March 29, 1929.

Memoir 124, *The Rhizoctonia Damping-off of Conifers, and Its Control by Chemical Treatment of the Soil*, was mailed on July 30, 1929.

